RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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1914.

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OF
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GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE YEAR 1913. BY H. H. HAYDEN, C.I.E., D.Sc., *Director.*

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DISPOSITION LIST.

1. During the period under review the officers of the Department were employed as follows :—

Superintendents.

MR. C. S. MIDDLEMISS .	Returned to headquarters from the field on the 15th April 1913. Proceeded to Kashmir on the 16th June 1913 to continue the Geological work on which he had been engaged during the previous year. Returned to headquarters on the 8th November 1913. Proceeded on privilege leave for 1 month with effect from the 17th December 1913.
MR. E. VREDENBURG . .	Returned to headquarters from the field on the 2nd April 1913. At headquarters, engaged on the description of Indian Tertiary fossils.
DR. L. L. FERMOR .	Returned to headquarters from the field on the 21st April 1913. Granted privilege leave for 2 months and 24 days and in continuation furlough for 1 year 3 months and 6 days with effect from the 15th May 1913. Placed on deputation in August, to attend the 12th International Geological Congress in Canada.

Assistant Superintendents.

MR. P. N. DATTA .	Returned from the field on the 17th April 1913. Retired from the service with effect from the 25th June 1913.
DR. G. E. PILGRIM .	At headquarters as Palæontologist and in charge of office. Granted privilege leave for 1 month and 8 days with effect from the 26th August 1913. Returned from leave on the 18th October 1913.
MR. G. H. TIPPER .	Returned to headquarters on the 24th April 1913. Elected a co-opted member of the Royal Commission on the Public Services. Proceeded to Delhi to join the Commission on the 1st November 1913. Returned to headquarters on the 13th November 1913. Placed in charge of the Burma party and left for the field on the 14th November 1913.
MR. H. WALKER . .	Returned from the field on the 30th April 1913. Granted privilege leave for 2 months and 14 days combined with special leave for 3 months and 17 days with effect from the 25th October 1913.
DR. E. H. PASCOE .	Returned to headquarters on the 29th April 1913. Placed on deputation to the Persian Gulf on October 15th.
MR. K. A. K. HALLOWES	Returned from leave on the 1st August 1913. At headquarters.

MR. G. DE P. COTTER .	Returned from the field on the 1st April 1913. Posted to the Burma party and left for the field on the 7th November 1913.
MR. J. COGGIN BROWN	At headquarters as Curator, Geological Museum and Laboratory.
MR. J. J. A. PAGE .	Returned from the field on the 30th April 1913. Resigned the service with effect from the 16th October 1913.
MR. H. C. JONES .	Returned to headquarters on the 30th April 1913. Deputed on the 10th May 1913 to report on quarries and stone in connection with the building of Imperial Delhi. Returned to headquarters on the 9th June 1913. Re-posted to Central India and Rajputana party to continue the systematic survey in the States of Gwalior, Nimbahera and Tonk and left for the field on the 4th November 1913.
MR. A. M. HERON .	Returned from the field on the 30th April 1913. Acted as Lecturer on Geology, College of Science, Poona, from May till September. Re-posted to the Bombay, Central India and Rajputana party and left for the field on the 27th October 1913.
DR. M. STUART . .	Services temporarily transferred (from the 18th February 1911) to the Madras Education Department to act as Professor of Geology at the Presidency College, Madras.

quartz grains in a matrix of small brecciated felspar fragments, green amphibole and a little pyroxene. This rock is regarded as a hybrid pyroxene gneiss, and as undoubtedly produced by the intermingling of the pegmatite magma with the pyroxenite and the subsequent recrystallization of the whole as a felspar-quartz-amphibole rock.

Andesite in Korea coal-field.

21. An interesting type of rock, which has been designated as an unusual variety of andesite, was found by Dr. L. L. Fermor in the neighbourhood of Chirmiri near Kurasia in the Korea State in the Central Provinces. The rock in question is vesicular, and would at first sight appear to be a surface lava. Its linear distribution, however, suggests a dyke, a supposition which is borne out by the fact that it contains fragments of the Gondwana rocks with which it is associated. On the other hand, the rock appears occasionally to be almost pumiceous in character, and this, with its vesicular nature, would lead to the conclusion that it was extrusive. On the whole, Dr. Fermor leans to the conclusion that the rock is intrusive. Under the microscope it is found to be of felspar microlites in a colourless to black glassy matrix, often vesicular. In the most coarse-grained crystalline variety the laths are found to consist of labradorite, set in a glassy matrix containing skeleton crystals of magnetite, but no augite. The rock, therefore, appears to be an unusual variety of andesite corresponding in composition to the ground-mass of a typical andesite, the ferro-magnesian silicates being absent.

PALÆONTOLOGY.

Tertiary mammals.

22. Dr. G. E. Pilgrim acted as Palæontologist throughout the year. He was engaged on the examination of the specimens collected by himself and by Sub-Assistant Vinayak Rao, which enabled him to form the conclusions embodied in his paper on "The correlation of the Siwaliks with mammal horizons of Europe," which has already been published in the preceding volume of these *Records*.

Tertiary molluscs and nummulites of Sind.

23. From the date of his return from the field early in April until the end of the year, Mr. Vredenburg was employed at head-quarters in completing his description, on which he has been engaged

for the past eight years, of the Tertiary fossils of Western India. It is hoped that this may be ready for the press in the course of the next few weeks. He has also revised his descriptions of the nummulites of Western India, which was completed some years ago but has not yet been published owing to the difficulty met with in obtaining satisfactory photographs of the specimens described.

Echinoids of Baluchistan and Tibet.

24. In addition to his work on Tertiary *Mollusca* and *Foraminifera*, Mr. Vredenburg has re-examined certain Cretaceous and Tertiary echinoids collected in Baluchistan and in Tibet, and finds that some of the generic determinations, originally made by Dr. Noetling, require some slight modification. Thus the species *Echinanthus Griesbachi* appears to belong to a genus which does not strictly conform to the characters of *Echinanthus*, and is probably new. Again, *Pyrina gigantea* Noetling appears to belong rather to the genus *Echinoconus*, and seems to be specifically indistinguishable from *Echinoconus Douvillei* from the Maestrichtian of Persia. The Tibetan echinoids come from the Kampa system, and appear to belong to three separate faunas, the oldest being Cenomanian, the next Maestrichtian, and the third probably Eocene.

Palæontological work in Europe.

25. During the year under review, descriptive palæontological work on behalf of the Geological Survey has been carried out in Europe by Professor A. C. Seward and Mr. F. R. Cowper Reed at Cambridge, by Professor H. Douvillé in Paris and by Dr. C. Diener in Vienna. Mr. S. S. Buckman has also continued his investigations with regard to the brachiopods of the Northern Shan States. Among the results of the above work may be recorded a paper on *Camarocrinus asiaticus* by Mr. Cowper Reed, and an account of the Anthracolithic fossils of Kashmir and Spiti by Dr. Diener. The former paper, which has already been published in these *Records*, deals with certain features not preserved in the specimens which had been previously described and adds considerably to our knowledge of the species. Dr. Diener's description of the Anthracolithic faunas of Kashmir and Spiti deals with the large collections made during recent years by Mr. C. S. Middlemiss from the Carboniferous and Permian rocks of Kashmir, and the collections made by me during the summer of 1901 from the

MR. N. D. DARU . .	Returned from the field on the 30th April 1913. Granted privilege leave for 3 months with effect from the 8th July 1913. Returned from leave on the 16th October 1913. Deputed to Bombay to conduct examinations in Geology at the Bombay University from 30th October to 3rd December 1913. Re-posted to Bombay, Central India and Rajputana party and left for the field on the 4th December 1913.
MR. H. S. BION .	Returned from the field on May 2nd; accompanied Mr. Middlemiss to Kashmir for field work on the 16th June 1913. Returned to headquarters on the 9th November 1913. Posted to Burma party for geological survey of Minbu and Pakokku districts and left for the field on 16th December 1913.
MR. C. S. FOX .	Returned from the field on the 16th April 1913. Deputed to report on the water supply of Ranchi during the middle of May 1913. Re-posted to the Central Provinces party and left for the field on the 6th October 1913.
MR. R. C. BURTON	Returned to headquarters on 19th April 1913. Re-posted to the Central Provinces party and left for the field on the 20th October 1913.
MR. R. W. PALMER	Joined the Department on the 13th December 1913.

Chemist.

DR. W. A. K. CHRISTIE At headquarters.

Sub-Assistants.

S. SETHU RAMA RAU . Returned from the field on the 29th April 1913. Granted privilege leave from 15th September to 3rd October 1913. Attached to the Burma party and left for the field on the 2nd November 1913.

M. VINAYAK RAO . Returned from the field on the 29th April 1913. Granted privilege leave from 16th to 18th October 1913. Attached to the Central Provinces party and left for the field on the 3rd November 1913.

Assistant Curator.

MR. A. K. BANERJI . At headquarters.

Field Collector.

BANKIM BEHARI GUPTA. Returned from the field on the 31st March 1913. Granted privilege leave for 2½ months from 17th November 1913.

ADMINISTRATIVE CHANGES.

Appointments and promotions.

2. Mr. R. W. Palmer, M.Sc. (Manch.), joined the Department on the 13th December 1913.

Dr. G. E. Pilgrim, Assistant Superintendent, was appointed to officiate as Superintendent, *vice* Dr. L. L. Fermor on leave from 15th May 1913.

Leave.

3. Mr. C. S. Middlemiss was granted privilege leave for 1 month with effect from the 17th December 1913.

Dr. L. L. Fermor was granted privilege leave for 2 months and 24 days and furlough for 1 year 3 months and 6 days with effect from the 15th May 1913.

Dr. G. E. Pilgrim was granted privilege leave for 1 month and 8 days with effect from the 26th August 1913.

Mr. H. Walker was granted privilege leave for 2 months and 14 days combined with special leave for 3 months and 17 days with effect from the 25th October 1913.

Mr. N. D. Daru was granted privilege leave for 3 months with effect from the 8th July 1913.

S. Sethu Rama Rau was granted privilege leave from 15th September to 3rd October 1913.

M. Vinayak Rao was granted privilege leave from 16th to 18th October 1913.

Retirement and resignation.

4. Mr. P. N. Datta, Assistant Superintendent, retired from service with effect from the 25th June 1913. Mr. J. J. A. Page, Assistant Superintendent, resigned the service with effect from the 16th October 1913.

PUBLICATIONS.

5. The publications issued during the year under review comprise one volume of Records, three of Memoirs and two memoirs of *Palæontologia Indica*.

LIBRARY.

6. The additions to the Library during the period 1st January to 31st December 1913 amounted to 3,307 volumes, of which 1,954 were acquired by presentation and 1,353 by purchase.

GEOLOGICAL CONGRESS.

7. Advantage was taken of the circumstance that Dr. L. L. Fermor was in England on leave during the summer, to arrange that he should be placed on deputation in order to attend the 12th International Geological Congress, which was held at Toronto in August. Dr. Fermor was at the same time especially suitable to represent the Geological Survey of India, since he was thus given an opportunity of studying the crystalline rocks of Canada which present problems analogous to many of those confronting geologists working amongst the Archæan areas of India, and more especially in the Central Provinces, where Dr. Fermor's survey party is at present engaged. Dr. Fermor was permitted to take part in several excursions of great interest and was thus enabled to make extensive collections which have now been forwarded to Calcutta. His full report will be published subsequently in these *Records*.

MUSEUM AND LABORATORY.

Staff.

8. Mr. J. Coggin Brown was Curator of the Museum and Laboratory throughout the year. Mr. Ajit Kumar Banerji was Assistant Curator during the same period. Babu Durga Sankar Bhattacharji continued to work as Museum Assistant, Mineralogical Section.

Determinative and assay work.

9. The number of specimens referred to the Curator for examination and report was 723, an increase of 371 on the previous year. Assays and analyses were made on 82 of these, an increase of 35 over the figures for 1912. The above lists include the classification of a collection of minerals and rocks for the Quetta Museum, and the petrological examination of rocks from Tibet collected by Captain Bailey, from Hunza and the Taghdumbash Pamir by Lieutenant K. Mason, R.E., and Captain H. W. G. Hingston, I.M.S., and from the Zanskar range by Dr. A. Neve of Srinagar. The more important chemical work included the assay of a large number of gold-bearing concentrates from the upper Chindwin and of numerous samples of coal from the Korea field.

Meteorites.

10. Two Indian meteorites were received during the year. One fell in Banswalgaon, Chaman Sari village, Mussoorie sub-division, on the 12th January 1913, at about 6 P.M. Only small fragments weighing 13·77 grms. have been recovered. A description of this meteorite by the

Curator has been published in these *Records* (Vol. XLIII, pp. 237-240). The other, a representative of the rare group of carbonaceous chondrites, fell at Chhabra in Tonk at about 4 P.M. on the 22nd January 1911. It was presented to the Geological Survey, through the Astronomical Society of India, by His Highness the Maharaja Rana Bahadur of Jhalawar. and has been analysed and described by Dr. W. A. K. Christie. The total weight of the small fragments is only 7·729 grms.

Specimens of the St. Germain du Puel and the Amalia iron meteorites were acquired by exchange with Julius Bohm of Vienna and the Foote Mineral Company of Philadelphia respectively.

Donations to Museums, Educational Institutions, etc.

11. Numerous requests are received from time to time from Educational Institutions in India for collections of typical specimens of Indian minerals and rocks, and during the year it has been possible to comply with several of these. A typical series of Indian minerals of economic importance was presented to the Manchester University. Other donations were made to Professor U. Grubenmann of Zurich, to Dr. T. L. Walker, Royal Ontario Museum of Mineralogy, Toronto, Canada, and to Professor A. Lacroix, Musée d'Hist. Naturelle, Paris.

Exchanges of Indian minerals and rocks.

12. The following minerals and rocks were exchanged during the year :—

12 specimens of Indian laterites, with the United States National Museum. Washington, for specimens of ferberite, zunyite and mixite, and Nevada silver-ores.

22 manganese-bearing minerals and rocks, with Dr. L. Eger, Naturhistorisches Institut, Vienna.

16 manganese-bearing minerals and rocks with the Foote Mineral Company, Philadelphia, Pa., U. S. A., in exchange for specimens of yttrofluorite, brugnatellite, strüverite, titan-olivine, glaucophane, davidite, hulsite, hinsdalite and ænigmatite.

New specimens acquired by donation.

13. The following are among the specimens acquired by donation during the year :—

(1) aluminium nitride, presented by Mr. P. C. Dutt, B.L., Jubbulpore ;

(2) coal from Raniganj, presented by Mr. P. C. Dutt ;

(3) amblygonite, spodumene, lithiophyllite and lepidolite, presented by the Shaefer Alkaloid Company, New Jersey, U. S. A;

(4) manganese-ores from Ranpur State, Puri district, presented by Mr. T. Chaudhari;

(5) wolfram from Mergui, presented by Captain T. L. Bomford, I.M.S;

(6) hambergite from the Padar sapphire mines, Kashmir, presented by Mr. C. M. P. Wright;

(7) manganese-amphibole from Mansar manganese mine, Nagpur district, Central Provinces, presented by the Central Provinces Prospecting Syndicate, Ltd.:

(8) various specimens of minerals from Madagascar, presented by Professor Lacroix, including blomstrandite, corundum, amazonite, pink beryl, orthoclase, lepidolite, rubellite, manganapatite, bismuthite, euxenite and striiverite.

Minerals received by exchange.

The following minerals were received in exchange from Dr. Eger:—

aphthitalite	from Artio del Cavallo.
canfieldite (a complex sulphide of silver and tin, containing germanium)[1]	„ Freiburg, Saxony.
chloromanganokalite (a double chloride of potassium and manganese with the probable formula $KCl.MnCl_2$)[2]	„ Vesuvius.
neochrysolite	„ „
nocerite	„ „
pseudobrookite	„ Piski, Transylvania.
ptilolite	„ San Piero, Elba.
rosenbuschite	„ Langesund Froid, Norway.
orangite	„ Norway.
wiikite (a rare earth mineral containing scandium)[3]	„ Finland.
euxenite	„ Mitchel, S. Dakota, U. S. A.
radioactive barytes	„ Karlsbad, Bohemia.
uranocircite	„ Falkenstein, Saxony.
atelite	„ Vesuvius.
cavolinite	„ „
cuspidine	„ „
meionite	„ „
vesbine	„ „

[1] S. L. Penfield, Am. J. Sc. 47, p. 451, 1894.
[2] H. J. Johnston-Lavis & L. J. Spencer, Min. Mag. 15, p. 54, 1908.
[3] Sir W. Crooks, Proc. Roy. Soc. 80, pp. 516-518, 1908.

Mineral Gallery.

14. The work of re-arranging and re-labelling the mineral collections has been continued. The vernacular names of many of the more important species have been added to the labels.

Duplicate collections.

15. Babu Bankim Behari Gupta, Field Collector, was employed during the season in collecting manganiferous minerals and rocks of the Kodurite series, from the Vizagapatam district, and of the Gondite series, from the Nagpur district. The duplicate collections have been further increased by various specimens originally sent in for determination in the laboratory.

16. Dr. W. A. K. Christie has been engaged chiefly in an investigation of the salt deposits of the Punjab Salt Range and the vexed question of their origin. Discarding the igneous theory of their genesis, which had previously met with some acceptance, he shows, in a paper now in the press, that the peculiar features presented by the deposits can best be explained by adopting a sedimentary hypothesis, and that the anomalous stratigraphical relationship obtaining between them and the other formations of the Range is mainly due to isostatic adjustment of the salt deposits, which the pressure of superincumbent strata had rendered plastic. Detailed analyses of samples, taken at intervals of a few inches from hanging to foot-wall of the seams of potassium salts intercalated in the rock-salt beds, have led him to the conclusion that all of these are secondary in character, their metamorphosis from the original mineralogical condition in which they were deposited having been occasioned chiefly by the depression of the beds to a hotter geothermic horizon. The economic possibilities of the potassium deposits are also discussed. Besides the miscellaneous work of the laboratory an investigation has been made of the remarkable Tonk meteorite, which fell at Chhabra in 1911. A description of it, with a full analysis, is published in this part of the *Records*.

17. The rearrangement of the Invertebrate Fossil gallery is being continued, under the superintendence of Dr. G. E. Pilgrim, on a revised plan. A systematic classification of the entire duplicate collection of Indian fossil invertebrates is being adopted, primarily according to main geological systems and secondarily according to main localities.

18. Three new show cases have been placed in the Siwalik gallery, thus filling all available floor space. In one of these cases the foreign *Carnivora* have been arranged, while two additional cases have been allotted, one to the Indian *Suidæ* and another to the Indian *Perissodactyla.*

An interesting addition to the Fossil Vertebrate collections is the skull of *Hipparion* from Perim Island, described and figured by Lydekker under the name of *Hipparion antilopinum* Falc. et Caut. in Pal. Ind., ser. 10, III, p. 11, Pl. 3. This skull was formerly the property of Mr. Theodore Cooke, and at his death it was feared that this valuable type might be in danger of being lost. Various efforts to trace its whereabouts were therefore made, but proved unavailing until Mr. N. D. Daru was fortunate enough to find it in the College of Science, Poona. The College authorities have now generously presented it to the Geological Survey. Dr. Pilgrim considers, from an examination of the actual specimen, that it is specifically indistinguishable from the skull of *Hipparion punjabiense* Lyd. from the Middle Siwaliks of Dhok Pathan, and therefore proposes to abolish his species *Hipparion perimense* which he had formerly introduced for it.

MINERALOGY AND PETROLOGY.

Hambergite from Kashmir.

19. Amongst the collections of minerals brought by Mr. C. M. P. Wright from the sapphire mines of Padar in Zanskar were found some crystals of hambergite, a mineral not hitherto recorded as occurring in India. The specimens were examined and a description of them has already been published by Mr. R. C. Burton in Vol. XLIII of these *Records.*

Hybrid pyroxene gneiss.

20. Numerous crystalline rocks of interest have been recorded by Messrs. Fox and Burton in the course of their work in the Central Provinces. One of these may be referred to here, being regarded by Mr. Burton as one of the peculiar forms known as hybrid rocks. The rock in question occurs at the junction between a coarse pegmatite and a mass of pyroxenite which has been caught up in the pegmatite. Near the contact the pegmatite contains green amphibolite and is welded on to the hybrid rock, which consists of large white and pink porphyritic crystals of felspar and irregular

Carboniferous rock of Bashahr and Spiti. The fossils from Kashmir were derived from the Syringothyris limestone, from the Fenestella series and from the Zewan beds. The fauna of the Syringothyris limestone, although rich in individuals, is poor in number of species, there being altogether fourteen species of brachiopods, of which, however, only four were found to be specifically determinable. The presence of *Syringothyris cuspidata* Mart., however, indicates that this horizon, like the Lipak limestone of Bashahr, is of Lower Carboniferous age. The fossils from the Fenestella series are much more numerous and include altogether 41 species, of which thirty are brachiopods, six lamellibranchs, three *Bryozoa*, one a *Conularia*, and one a trilobite. Although our knowledge of the fauna of the Fenestella beds of Kashmir is thus considerably increased, the question as to their stratigraphical position is still doubtful. Out of the 41 species 20 are unfortunately new, and are known only from the Fenestella beds, while 12 are so imperfectly known as to be of no critical value. The fauna, however, is markedly different from that of the Zewan beds, and Dr. Diener concludes that it is considerably older than Permo-Carboniferous. In certain respects it resembles that of the Lower Carboniferous and in others that of the Middle and Upper. Its age, therefore, as referred to the European stratigraphical scale, is still uncertain. The fauna of the Zewan beds is still more extensive, containing altogether 59 species distributed as follows: brachiopods 46, lamellibranchs 7, cephalopods 2, *Bryozoa* 2, gastropod 1, and *Anthozoon* 1. Again the brachiopods predominate enormously. The identity of the fauna of the Zewan stage with that of the Productus shales of Spiti and the Central Himalaya generally is attested by the fact that out of 44 species of the former fauna which are specifically determinable 33 are common to both; *Xenaspis carbonaria*, which had already been found in the Salt Range, in Kumaun, and in Spiti, has now been found also in Kashmir.

26. The fauna from the Carboniferous limestone of Bashahr and Spiti contains only 24 forms which are specifically determinable. Several of these, however, are characteristic, and include *Syringothyris cuspidata*. The fauna, on the whole, is closely related to that of the European and American Lower Carboniferous. It is hoped that Dr. Diener's paper will be published in the *Palæontologia Indica* during the current year.

ECONOMIC ENQUIRIES.

Building Stone.

Marble and sandstone.

27. In connection with the preparation of plans and estimates for the building of Imperial Delhi, the services of an officer of this Department were urgently called for during the last hot weather in order that he should accompany an engineer of the Public Works Department on a visit to certain quarries in Central India and Rajputana with a view to reporting on the quality and quantity of building stone likely to be obtainable from them. Mr. H. C. Jones was instructed to take up the work, and left Calcutta about the middle of May, the most unfavourable time of the year at which to take up an investigation of the kind. Mr. Jones deserves great credit for the promptness with which he responded to the call on his services and the thorough manner in which he carried out the work under the most trying climatic conditions. The investigations were largely restricted to Native States in which are to be found most of the suitable marble and sandstone lying within reasonable distances from Delhi. The stone required included white marble, black marble, buff sandstone and dark red sandstone. In the case of the marble deposits, very little quarrying and practically no prospecting had been done previously, whilst, in the case of sandstone, the rock has frequently been very irregularly quarried, the old quarries being filled and the surface covered with débris. No reliable information, therefore, could be obtained as to the amount of rock available in most of the old quarries.

28. White marble was found to occur in large quantity, but rarely free from crystals of yellowish-green tremolite, which spoils the appearance of the rock. The best marble found was that of Maundla in Jaipur. A good marble similar to that of Maundla occurs also near Dhadakir in Alwar, but lies at a considerable distance from the railway.

29. The difficulty of obtaining black marble in India is not a new one, most of the so-called black marbles being usually gray. The best material within reasonable distance of Delhi appears to be that which occurs at Bhainslana in Khetri. It has been found by Mr. Heron to occur amongst a group of crystalline limestones, furnishing a variety of marbles of all colours which are in extensive use for local demands. The quarries, however, are situated

at a great distance from the railway. A black shale, which might serve the purpose of black marble, is found near Kho in Alwar.

30. Large quantities of buff sandstone were found to be easily obtainable from quarries already in operation in the Dholpur State. The dark red sandstone, which is so familiar from its use in the Moghul buildings of Delhi and Agra, is frequently mottled with buff spots, which detract seriously from its appearance, but stone of good quality and in large quantity appears to be available in the Paharpur quarries in Bharatpur State and in the Nurpur quarries in Dholpur State.

31. Considerable difficulty has recently been experienced in obtaining marble from Makrana at a sufficiently rapid rate for the requirements of the Victoria Memorial now being erected in Calcutta. I paid a visit to the Makrana quarries early in the year and subsequently accompanied His Excellency the Governor of Bengal on a visit to them in September. The quarries were examined in detail, and it was found that the quantity available was ample for the purpose. Certain recommendations were made as to the extension of the present quarries, and these, if adopted, will probably result in an increase in the rate of output.

32. During his survey of Jaipur, Mr. Heron visited the freestone quarries of Raghunathgarh (lat. 27° 40′; long. 75° 23′). The rock is white and fine-grained and is obtained in very large, thick slabs, which are despatched often to great distances. There is a considerable local trade in quarrying and carving the stone, which would be more extensively used if the locality were not so far from the railway.

Coal.

Korea coalfield.

33. At the request of the Chief Commissioner of the Central Provinces, Dr. L. L. Fermor undertook the examination of the coalfields lying in the Korea State and previously referred to in *Memoirs*, G. S. I., Vol. XXI, pt. 3. These fields lie on the continuation of the Rewah Gondwana basin. The area examined falls conveniently into two fields, which Dr. Fermor has named the Sanhat field and the Kurasia field, the latter being sub-divided again into the Kurasia area and the Chirmiri area. In the Sanhat field two seams were examined, the lower of which is valueless in the western half of its course, but shows thicknesses of over 4 to 9 feet over a length of 16 miles in the eastern part of the field. The upper seam is valueless

in the east, but ranges from 3½ feet to nearly 10 feet in the west. The result of a considerable number of assays shows that neither seam is of good quality, the ash content ranging from 15·38 per cent. to 32·24 per cent. in the case of the lower seam and from 22·98 to 36·68 per cent. in the case of the upper. In the Khurasia field 6 coal horizons were found, in one of which (horizon 4) there are from 2 to 5 seams, ranging in thickness from 1 foot to 8 feet 6 inches This horizon is supposed to cover about 4 square miles, in which case an average thickness of the coal of, say, 5 feet would correspond to 5½ million tons per square mile. This, however, must still be proved by boring. Numerous samples taken show that the coal of this area is better than that of the Sanhat field, the ash content ranging from 9·32 per cent. to 13·82 per cent., the average composition of all samples being—

	Per cent.
Moisture	8·66
Volatile matter	30·92
Fixed carbon	48·86
Ash	11·56

The dip of the coal ranges from 5° to 15° to N. N. W.

34. Still better coal is found in the Chirmiri area of the Kurasia field, where the finest seam of coal in the State is exposed in the Kauria stream above and below a waterfall known as the Karar Khoh. Seven seams, aggregating 13 feet in thickness, were observed, the average assay value being—

	Per cent.
Moisture	7·7
Volatile matter	29·1
Fixed carbon	51·2
Ash	12·0

This series of seams appears to thin out gradually in all directions; but Dr. Fermor considers that there is from 1 to 1½, possibly even two, square miles, over which the coal is at least 10 feet thick. It is estimated, therefore, that at least 7 million tons of good coal are available, possibly a considerably larger quantity. The dip of the seams is always very low, usually almost horizontal.

35. Both the above fields show faulting, although not on an extensive scale, the faults being generally small and not very numerous. On the other hand, the seams are frequently found to

vary greatly in thickness in a short distance. The roof is usually sandstone, massive and, though rather friable, probably fairly sound. A complete account of these coalfields is now in the press, and will be published shortly in the *Memoirs*.

Cobalt.

Jaipur.

36. The *sehta* (cobaltite and danaite) of the Babai (lat. 27° 53′; long. 75° 48′) and Bagor copper mines in Jaipur (*see* V. Ball, *Man. Geol. India*, pt. 3, p. 324, and F. R. Mallet, *idem*, pt. 4, p. 27), Mr. Heron remarks, was worked until as recently as only four years ago, when it was displaced by a dearer but purer imported substance for use by the Jaipur enamellers. The *sehta* consists of minute silvery crystals sparsely scattered through the same black slates which contain the copper pyrites (see *infra*). These come below the quartzite on which the Khetri and Bagor forts stand and are almost continuous from Singhana to Babai. The workings are quite irregular and follow the general direction of the dip of the slates at a steep angle of from 30° to 60°. The ore is in irregular strings, layers and lenticles, without any semblance of a true lode. The black slate country rock is more or less siliceous and splintery with indefinite bands of impure quartzite and amphibolite intrusions.

Copper.

Jaipur.

37. Mr Heron during his survey of Jaipur visited the old and well-known copper mines at Singhana. Khetri and other places in the State (see Ball, *Man. Geol. India*, pt. 3, p. 260). No work is reported as proceeding now except casually for the extraction of alum, copper sulphate and ferrous sulphate from the efflorescence which coats the walls of the mines, though Mr. Heron remarks that there appears to have been a revival of the industry as recently as 12 years ago during the reign of Rajah Jai Singh. Among the various reasons given for the stoppage of the works none appear to be due to exhaustion of the ore, competition with imported copper or scarcity of fuel. Mr. Heron says: "I saw a lot of ore in the walls, and the miners say that beneath the water which partially fills the mines there is abundance still untouched. The mines are in a very ruinous and dangerous state . . . Adequate

exploration of the mines and proper arrangements for their drainage by horizontal adits and water lifts would be an expensive business and would require perhaps several years of consistent policy, but the possible profit is greater than that held out by many enterprises engaged in by Native States."

38. At the request of the Dholpur Durbar, Mr. Heron visited a supposed copper mine in that State near the fort of Kuargarh. The copper, however, was found to consist of only small quantities of malachite occurring along joints and between the grains of the sandstone, such little quantity as there was having now been almost entirely removed Mr. Heron thinks it probable that the mine was formerly merely a stone quarry in the Upper Bhander sandstone.

Dholpur.

Gold.

39. Mr. H. S. Bion completed his investigation of the gold-bearing alluvium of the Chindwin river, and the results have already been published in these *Records* (Vol. XLIII, pt. 4). After examining all the important localities, Mr. Bion came to the conclusion that the Chindwin gravels cannot be worked profitably except on the small scale at present adopted by the local inhabitants.

Burma.

40. Mr. R. C. Burton records the occurrence of gold in the sands from the river beds of the Bawenthuri and Pachdar streams in the Seoni district of the Central Provinces. Washing is carried on by the natives during the rains, the average amount won being only 3 or 4 annas worth per man per diem.

Central Provinces.

Gypsum.

41. Mr. Heron paid a visit to the gypsum deposit which occurs in the Chamba valley in Dholpur State. This was found to be a local lacustrine deposit containing fresh-water shells. It is small and of no economic value.

Iron.

42. Among many occurrences of this mineral in Jaipur State Mr. Heron specially mentions a locality 1¼ miles west of Raipur (lat. 27° 44'; long. 76° 0') where two vertical bands of massive hematite varying from 3 to 15 feet in width, and apparently free from visible

impurities, occur in mica schist and are traceable at intervals along the strike for 2 miles.

Manganese.

Central Provinces.

43. Small deposits of manganese are recorded by Mr. R. C. Burton from the area to the south of the Korai ghats in the Seoni district of the Central Provinces. Some of the localities enumerated might possibly be worth exploration. These are :—

(1) on the Bhandara-Seoni boundary S. W. of Khirki, where quartzite is found impregnated with manganese-ore ;

(2) ¼ mile west of Dhobitola, quartzite impregnated with manganese-ore is found interbedded with two or three thin bands of fairly pure ore ;

(3) on the same road from Dhobitola to Dulapur, a small band of ore occurs 200 yards east of Thuyaghak stream ;

(4) 600 yards west of the same stream a small outcrop of ore occurs on the road ;

(5) an outcrop of manganese-ore with blue quartzite is found at the western edge of a small hillock about 250 yards north of Chichuldoh village. It is from 20 to 25 yards wide, and was traced for about 160 yards to the west of the hill. It is of poor quality, consisting largely of gondite impregnated with manganese-ore ;

(6) small blocks of ore were found to the west of Chichuldoh, and a small deposit is seen in the stream half a mile to the south-west of the village. These, however, are thin bands, probably of no importance.

Dholpur.

44. At the request of the Dholpur Durbar Mr. Heron visited Kesarbagh, where manganese-ore was supposed to occur. Only very small quantities were found occurring in the form of a few plates deposited along joint-planes. The occurrence is of no economic value.

Petroleum.

Punjab and North-West Frontier Province.

45. During a part of the year Dr. E. H. Pascoe was engaged on an investigation of the petroliferous localities of the Punjab and the North-West Frontier Province.

His work was unfortunately interrupted, first, by illness, and subsequently by deputation out of India, and it is hoped that the work may be resumed next field-season.

The following areas were visited :—

(i) Sudkal, near Fatehjang, in the Rawalpindi district. Three well-known seepages of oil occur here, 3 miles N. W. of Fatehjang. The rocks exposed belong to Wynne's "Upper Nummulitics," which probably include some of Mr. Middlemiss' Kuldanas. They consist of nummulitic bands interstratified with iron-stained sandstones or clayey sands and occasional "pseudo-conglomerates." Nummulites are extremely plentiful and poorly preserved pelecypods and gastropods occur. The structure is complex and ill-suited for oil-retaining purposes. Two or three tightly packed and deeply denuded small anticlines, separated by equally small synclines, characterise the area, extending in an E.-W. direction. The seepages probably occur on a dip fault.

(ii) Chharat, five or six miles W. N. W. of Fatehjang. There are several seepages here, lying upon an E.-W. fold. The rocks are identical with those at Sudkal. The crest of the anticline is sharply bent and the narrow fold deeply denuded. The prospects of obtaining oil in commercial quantity are scarcely less inferior to those at Sudkal.

(iii) Jafar, 1½ miles S. W. of Chharat. There are no natural surface indications of oil at this spot, which was inspected because a boring put down in 1869] is reported to have met with a slight trace of oil. The structure is unfavourable and there is considerable doubt whether any trace of oil was actually found, as reported.

(iv) Chak Dalla, 3 miles N. N. E. of Bhatiot. Two seepages of bitumen are recorded in the Kala Chitta Range to the north of the Potwar plateau, but one appears to have been covered up. The rocks are nummulitic in age, but different from those of the Potwar. They consist mostly of hard, massive, bluish limestone, weathering in a curious groove-like manner and showing here and there traces of nummulites. Thin soft bands full of nummulites and some horizons with pelecypods and gastropods

are not uncommon. Artificial groups of strata were mapped and the structure demonstrated to be that of a long tightly folded anticline pitching westwards towards the railway cutting. The fold is composed of a thick series of beds and has been denuded sufficiently to leave very little of the crest behind. The fold, whose direction is E.-W., is much larger than those around Sudkal and Chharat, but the prospects from an oil-prospecting point of view are not good, and the intractability of the ground, the hardness of the rock, and the uncertainty of the existence of porous rock, offer little inducement to prospectors.

(v) Ratta Hotar, 10 miles N. of Rawalpindi. The rocks are similar to those at Chak Dalla and consist for the most part of massive limestone with traces of nummulites here and there. This limestone is faulted against the red shales, pseudo-conglomerates and olive sandstones of the Murree series, and has been severely folded in an intricate way. A small seepage of oil associated with hydrogen sulphide occurs not far from the fault. The severe folding and impervious nature of the beds are unpromising.

(vi) Panoba, a day's march N. of Khushalgarh in the Kohat district. The rocks of this area which is more or less in a line with the Kala Chitta Range, are similar to those at Chak Dalla, but comprise a greater thickness of softer beds. The map shows a well developed anticline but little, if any, of the crest remains intact, as the fold has been deeply denuded, and the prospects of an oil supply are doubtful. Three seepages occur where the fold pitches.

Kotehri and the two salt localities of Malgin and Jatta were visited, since the salt and gypsum frequently smell of petroleum and are sometimes bituminous. The folding in these places is severe and in Jatta becomes very complex. Although, on account of their clear exposures, these areas are of much scientific interest, the only economic value they have, from an oil prospector's standpoint, is that they are excellent examples of localities unsuitable for the retention of petroleum.

Pitchblende.

46. Both pitchblende and uranium ochre have been known for many years to occur at the Singar mica mines in the Gaya district,[1] although no serious attempt had been made to ascertain the amount available. Recently, however, prospecting has been carried out by Mr. H. E. Tiery in conjunction with Messrs. Moll, Schutte & Co., of Calcutta, and a certain quantity of pitchblende obtained. In view of the interest of the occurrence, Mr. R. C. Burton was instructed in October to visit the locality. I am indebted to Mr. Tiery and Messrs. Moll, Schutte & Co. for giving Mr. Burton every facility to examine their workings. Mr. Burton reports as follows :—

"The pitchblende occurs in a pegmatite, which crops out on a hill known as Abraki Pahar lying due east of Banekhap and rising two hundred feet above the surrounding alluvium. The pegmatite has a maximum width of forty yards and is exposed above the alluvium for a distance of approximately three hundred and fifty yards in a direction E. 20 S. It is intrusive along the bedding of fairly coarse-grained muscovite schists dipping at between 30° and 50° N., masses of the schist being also caught up in the body of the pegmatite. At the junction between the pegmatite and the schists, the latter contain tourmaline crystals in large quantity. This pegmatite has been mined for many years as a source of mica; before the mining for pitchblende commenced, the only indication of uranium on the surface consisted of small amounts of light yellow uranium ochre associated with triplite; but, as the pits were deepened, nodules of pure pitchblende were met with. At present six pits are being excavated by Mr. H. E. Tiery, and in five of them traces of uranium ochre have been found. Practically the whole of the pitchblende found (4 cwts.) has been obtained from a single pit, but small nodules have recently been found in another. The maximum weight of a nodule of pitchblende from the first pit is 36 lbs.

"The pitchblende occurs as rounded nodules distributed throughout certain basic segregations in the pegmatite, which are several feet in diameter. In these basic segregations the following minerals

[1] T. H. Holland: *Mem., Geol. Surv. India*, XXXIV, p. 31.

occur, but not always together :—white and yellow mica, triplite, ilmenite, tourmaline, pitchblende and uranium ochre ; while columbite, zircon and torbernite have also been recorded.

"Of the above minerals triplite is the commonest and is generally associated with pitchblende and uranium ochre, being taken as an indication of the probable presence of these latter ; whereas, if tourmaline is present in quantity at any particular part of the pegmatite, triplite seems to be either absent or present in only small amounts. In the largest segregation yet met with large masses of triplite formed the outer ring, while towards the interior pitchblende and uranium ochre became more plentiful ; but as the segregation was quarried out large striated masses of ilmenite were revealed in association with the triplite. Quite close to the above another segregation occurred containing practically nothing but small books of white mica, showing the variability in composition of the pegmatite from place to place and the impossibility of prophesying where pitchblende may be found.

"The pitchblende occurs in several ways :—

(1) as rounded nodules easily detached from a matrix consisting of large blocks of triplite,

(2) as smaller nodules inside blocks of triplite,

(3) as nodules in the centre of enclosing nodules of felspathic material.

"The pitchblende in these cases is generally surrounded by a rim of uranium ochre. When the nodules of pitchlende have been removed, small amounts of uranium ochre are found distributed throughout the more acidic parts of the pegmatite surrounding the triplite ; bags of this poorer material are preserved for future examination. As far as can be determined from the amount of excavation, which has up to the present been made, there is no definite alignment, for the segregations containing pitchblende are distributed at random in the pegmatite ; and only systematic mining will reveal them ; there seems no reason why they should not be found at depth.

"In addition to the above deposit triplite has also been found in a tourmaliniferous mica pegmatite, now being worked for mica, within the village boundaries of Gualatti about 1½ miles from Banekhap. This pegmatite has the same strike as that on Abraki Pahar and contains blocks of triplite fairly pure except for the

presence of a little mica and quartz; the triplite is rarely intimately intergrown with the other minerals of the pegmatite, but is generally in moderately pure blocks."

Water.

Ajmer.

47. At the request of the Agent to the Governor General in Rajputana Mr. Heron was deputed to visit Ajmer with a view to reporting on the possibility of the presence of artesian water in its immediate neighbourhood. The ground was examined carefully, and Mr. Heron came to the conclusion that the conditions were quite unsuitable for the occurrence of artesian water.

Wolfram.

Marwar.

48. During my visit to the Makrana marble quarries in September last I was shown specimens of wolfram which were said to have been obtained from a hill in the neighbourhood of Degana railway station on the Jodhpur-Bikaner Railway, and I was requested by the Regent to make arrangements for the examination of the locality. I arranged therefore that Mr. Heron should visit the locality and investigate the occurrence. The result of his investigation showed that the wolfram occurred with quartz and biotite in veins traversing granite, and that, although not occurring in sufficient quantity to justify any great expense in erecting plants for working, it might perhaps be profitably exploited on a small scale by means of local labour.

GEOLOGICAL SURVEYS.

Bombay, Central India and Rajputana.

Messrs. C. S. Middlemiss, H. C. Jones, A. M. Heron and N. D. Daru.

49. The party at work in these areas remained unchanged from last year, and was constituted as in the margin. Mr. Middlemiss paid a visit of inspection and collaboration to Mr. Jones in the complicated region of Nimbahera district, Tonk, details of which will be found below (p. 28), and another to Mr. Daru on the frontier between Idar and Dungarpur States,

during which latter, geological boundaries were adjusted along the border and various other points of detail discussed. Mr. Daru accompanied Mr. Middlemiss over some of the eastern parts of Idar where the sequence in certain critical sections is better exposed than in Dungarpur.

Mr. C. S. Middlemiss: Idar State.

50. Mr. Middlemiss was only able to devote a month to his survey in the southern and south-eastern parts of Idar, where some few patches of unfinished country were awaiting completion. The area was entered by way of Talod and Modasa, Meghraj (lat. 23° 30'; long. 73° 33') being the first important halting place, whence traverses were made in several directions. In addition to details of mapping further evidence was accumulated illustrating the three-fold character of the formations which make up the older systems in this part, namely, the Aravalli system of older schists and gneisses, etc., the Delhi quartzite series lying unconformably above them, and passing upwards into the great phyllite formation of the eastern and south-eastern parts of Idar. Certain critical sections near Khercha were once more visited to illustrate the above unconformity of the quartzite series above the Aravallis. Elsewhere the Meghraj ridge of Delhi quartzite, that at Rampur, and the several digitations between Dev Mori and Od were all conclusively proved to be brachy-anticlines of that quartzite plunging beneath the Phyllite series, which eastwards appears to extend for long distances into Dungarpur (see last year's report, *Rec.*, *G. S. I.*, Vol. XLIII, p. 25).

51. A further continuation of the calc-magnesian rocks of the Dev Mori--Kundol section was found in the hollow in the hills of Delhi quartzite to the west of Kokapur (lat. 23° 31'; long. 73° 26'). This series, together with the Ghanta outcrop of steatite, probably constitutes one line of exposures, which would also appear from Mr. Daru's report to be continued in a N. N. E. direction across the Dungarpur boundary. Very little good steatite is exposed in the Kokapur section, but the area is almost entirely covered by quartzite débris from the surrounding hill-sides. Considerable quantities of magnesite are indicated and tremolite-calcite rock, as in the sections of Dev Mori and Kundol (see *Records*, *G. S. I.*, Vol. XLII, p. 52, 1912).

Mr. Middlemiss is now preparing an account of the geology of Idar State for publication.

Mr. H. C. Jones: Indore, Gwalior and Tonk.

52. Mr. H. C. Jones' sphere of work during a full season (November to April inclusive) lay in three closely related areas surrounding Neemuch town, namely, (1) the Rampura division of Indore State, (2) the country south of Neemuch in Gwalior territory, and (3) the Nimbahera district of Tonk. All fall within the 1″=1 mile standard sheets, Nos. 205, 206, 237, 238, 269 and 270 of the Central India and Rajputana Survey, and lie between lat. 24° 15′ and 24° 43′ and between long. 74° 30′ and 75° 58′.

Although a considerable tract of country was mapped by Mr. Jones in the Rampura division, as a northward continuation of his previous work carried out during the years 1907-1909, nothing of any special interest was observed beyond what had already been reported. In particular, owing to the prevalence of forest and the great height of the grass at the time of his visit, no further evidence was elicited tending to clear up the doubts still existing as to the actual Vindhyan horizons to which the Rampura quartzitic sandstone and the Suket shale should properly be assigned (see *Records, G. S. I.*, Vol. XIV, pt. 4, and XXXVIII, 1908, p. 63).

53. The mapping of the second area lying to the south of Neemuch was a continuation westwards of the same earlier survey by Mr. Jones in order to join up with that done the year before by Mr. Heron in Partabgarh State. Good progress with the map here too has been made among those geological features, such as laterite, Deccan Trap and Intertrappeans, which are comparatively simple in their arrangement. But the western margin of the two areas, where the Suket shales or their covering of trap come into contact with Hacket's Delhis and Aravallis in Nimbahera district and in Udaipur, has for some time introduced difficulties of delineation and interpretation that have caused a serious check.

54. With the object of solving some of the problems involved, Mr. Middlemiss, during the early hot weather, joined Mr. Jones and spent a month with him re-surveying the tract south and west of Nimbahera, but with only partial success so far. Complete success cannot be hoped for until free access is obtained to the State of Udaipur, since Udaipur territory surrounds, and even encloses, these more complicated western areas of the Nimbahera district. Another disability is the long stretches of alluvium which bury much of the solid geology out of sight. As a result

there remain only a few rather scattered and limited outcrops on which to base conclusions, and these present a bewildering multiplicity of strange rock facies.

55. Reserving all that is conjectural and provisional for discussion at a later period when more of the surrounding parts have been explored, the following few facts have been ascertained by the joint exploration of Messrs. Middlemiss and Jones. To the west of the meridian of Jawad, the Suket shales, in a set of gently undulating folds, become underlain by a particularly distinctive pale grey, compact and slabby limestone which is almost everywhere quarried into beautifully regular flags of from 10 to 12 feet long, by 3 to 4 feet wide, and 4 inches thick. These are used with great effect in the local buildings in Nimbahera and other towns, and are also exported to great distances by rail. This limestone which can be traced continuously from near Jawad to Nimbahera, and from there still further west at intervals as far as the undulating ground between Malan and Binota, is about 200 feet thick and passes downwards through a short thickness of impure purple limestone into several hundred feet of purple shale and then into a basement bed of purple grit, conglomerate and boulder-bed. The last, a few feet thick only, is composed of well rounded masses of quartzite, granite, gabbro and other rocks and was briefly referred to by Hacket (*Records*, *G. S. I.*, Vol. XIV, pt. 4).

56. Mr. Middlemiss considers that there can be no doubt whatever that in the strata exposed from the top of the Rampura sandstone scarp down to this Binota basal conglomerate one passes through a generally conformable sequence, the members of which have now been separately delineated in detail on Mr. Jones' map. It has also been ascertained that this series with the boulder-bed at its base lies above rocks of various type, prominent among which are massive quartzites (Hacket's Delhis) at one place and thin-bedded shales at another,—facts which suggest an unconformity. Beyond this the survey of this tract is in a tentative stage; to the west and south-west of Binota there follow fresh sequences of limestones, shales, quartzite and conglomerate beds, but all differing so widely from the characteristic flaggy Nimbahera limestone and its associated shales and conglomerates, that for the present all that one can say is that it seems probable that they are really much older. This new series and their intrusive granite and basic rocks must await further examination.

Mr. A. M. Heron: N. part of Jaipur State.

57. Mr. A. M. Heron also spent a full season (latter part of October to end of April) in the field, being occupied during the whole of this time in continuing the survey of Jaipur. This he practically completed by his examination of the second half of the State to the north of Jaipur city (lat. 26° 56′; long. 75° 52′) and west of longitude 76° 10′, including the division of Amber, the Torawati and Shekhawati nizamats and the Khetri and Sikar States.

The area is included within the 1″=1 mile sheets, Nos. 224, 225, 255 to 260, and 284 to 289, and represents about 3,500 square miles. In this large tract the solid geology is mainly concentrated in the Shekhawati range of hills which divides the country into two great plains to the north and south, and in the wild country to the east of meridian 75° 45′.

58. The Aravalli system is only very feebly, and sometimes doubtfully, developed at one or two localities as slender ridges of quartzite and schist dipping under the base of the Alwar series (Delhi system). Unlike the areas which adjoin Jaipur on the east and in which the geological sequence is much fuller, there are missing from the sequence in Jaipur both the Raialo limestone and quartzite at the base of the Alwar series, and likewise the Khushalgarh limestone and hornstone breccia at the base of the Ajabgarh series.

59. The remaining formations which alone are developed on a considerable scale are, therefore, the Alwar quartzite and the more argillaceous Ajabgarh or Mandan series. These present certain differences in their mode of occurrence from that which is customary in the more easterly area of Alwar State. Although at the surface the whole now presents a great array of interdigitating brachy-anticlines and synclines, the Ajabgarhs, instead of occupying subordinate synclinal valleys (outliers) folded into extensive massifs of Alwar quartzite, here constitute by far the major portion of the exposed rocks, whilst the Alwars emerge from below them as four main anticlines or anticlinoria (inliers), two being in the Shekhawati and two in the Torawati hills respectively. Generally over the area, and more especially in the Shekhawati hills, the boundary line between the two formations is somewhat indefinite in consequence of the absence from this part of the country of the Khushalgarh calcareous series.

60. Along with the intense folding into isoclines which the rocks have sustained, there has been an increase in their metamorphism with the production of mica schists, actinolite schists, tremolite rock, and less often with the formation of staurolite, garnet and graphite. They are also intruded by (1) numerous and closely approximating sheets, sills and *lit-par-lit* injections of (1) amphibolite, (2) granite bosses, and (3) pegmatite veins, in the above order of time and in far greater quantity than in the eastern area of Alwar.

61. Among the details given in Mr. Heron's chapter on the igneous intrusions special attention is drawn to the amphibolites or traps. In composition these are now represented chiefly by the minerals hornblende and interstitial quartz with a granulitic structure, the result, as Mr. Heron thinks, of re-arrangement under crushing of the minerals of a rock of originally dioritic or doleritic composition. They appear to have preferred as avenues for their injection the more micaceous schists and conglomerates, but in the case of the limestone rocks the opinion is hazarded that "the thinner trap sills have been to some extent absorbed with mutual chemical reactions, resulting in the formation of actinolite, tremolite and epidote as streaks and knots in the crystalline marble." That the amphibolites are older than the granite or the pegmatite veins is shown by direct transgression of the latter across the amphibolite sills.

Mr. N. D. Daru: Dungarpur, Sunth and Kadana.

62. With the exception of the time spent in Idar State with Mr. Middlemiss, Mr. Daru was occupied in continuing the survey of Dungarpur State, and he also passed south into the small neighbouring States of Sunth and Kadana (Rewa Kantha Agency) where he made a beginning of operations. The country is of much the same geological type as that surveyed last year. Considerable progress in provisional mapping and description has been made, but as regards the final subdivision and correlation of the various members of the metamorphic series, Mr. Daru admits the necessity for a re-examination and re-description of large portions in the light of his recent experience in Idar. So far as may be at present summarised, it seems likely that the bulk of the country consists of the younger phyllite system as in the adjoining part of Idar. This is here and there interrupted by ridges of quartzite—probably the Delhi quartzite —which in turn ring round, or

partly enclose, inliers of more highly metamorphic schists mixed with much igneous rock, the supposed equivalents of the older (Aravalli) system elsewhere.

63. A prominent feature is a number of bands and dyke-like assemblages of magnesian and calcareous rocks, namely, serpentine, talc, steatite, dolomite, magnesite and magnesian limestone, several of which can be identified with those described by Mr. Middlemiss from near Dev Mori, Kundol, Kokapur, etc., in Idar State. Some of the bands may be traced almost continuously from the one region to the other. From certain considerations, chief among which are the splitting of a band into two, their rapid variation in width, and the fact that they lie in contact with the younger phyllites as frequently as with the quartzites, Mr. Daru is inclined to ascribe to these rocks an igneous origin and to regard some form of actinolite rock as the parent.

Burma.

64. The party working in Burma during the field-season 1912-13 consisted of Messrs. Vredenburg, Datta, Cotter and Bion, and Sub-Assistant Sethu Rama Rau.

Mr. H. S. Bion : Chindwin river.

65. Mr. Bion was engaged on an examination of the auriferous gravels of the Chindwin river, while the remainder of the party were engaged on the continuation of the systematic survey of the Tertiary rocks of the Irrawadi valley.

Mr. E. Vredenburg : Yenangyaung.

66. Mr. Vredenburg spent the greater part of his time at Yenangyaung, where he was permitted to examine in detail the large collections of fossils belonging to the Burma Oil Company. He also visited some of the more important anticlines, and the volcanic areas of Popa in the Myingyan district and Shinmadaung in the Pakokku district. Mr. Vredenburg's observations have led him to believe that the fossils described by Dr. Noetling in his work on "The Fauna of the Miocene Beds of Burma" (*Pal. Ind.*, New Ser., Vol. I), include two separate faunas, an older and a younger, and that these two faunas are separated, one from the other, by an important unconformity extending throughout the Tertiary area in Burma. This unconformity is believed by him to occur within the Pegu series, dividing it naturally into an upper and a lower, the lower being the chief petroliferous

group of beds and the upper being either non-petroliferous or only very sparingly so. So far as Mr. Vredenburg's work has gone, this unconformity is chiefly a palæontological one, and no conclusive evidence of a general physical or stratigraphical break has been adduced. The hypothesis of the occurrence of this supposed extensive unconformity has not met with general acceptance on the part of other members of the Geological Survey working in Burma, and it would, therefore, be premature to modify at present our classification of the Tertiary system of that province. Further field-work and detailed examination of the very extensive collections of fossils made during the last few years by the members of the Burma party will no doubt decide the question. At present the more generally accepted belief is that the Pegu series, as might be expected in a series of estuarine or shallow-water deposits, contains a large number of small unconformities, none being of very great extent or of more than purely local importance.

Mr. P. N. Datta: Myingyan and Sagaing.

67. Mr. Datta continued the systematic mapping of parts of the districts of Sagaing, Myingyan, and Kyaukse. The rocks met with belonged entirely to the Pegu and younger series (Irrawadi series and alluvium).

Mr. G. deP. Cotter: Minbu and Pakokku.

68. Mr. Cotter worked during the early part of the season in the foot-hills of the Arakan Yoma to the west of Minbu, but, owing to a serious epidemic of malaria, which is said to have decimated some of the local villages, he was compelled to move to a less unhealthy locality, and he continued the survey of the lower beds of the Tertiary system (*Nummulitics*, Theobald) in the country between Pakokku and the Yoma. On returning to headquarters, Mr. Cotter devoted the recess to the detailed study of the fossils collected by him. These comprised nummulites and a considerable number of molluscs. The former have led Mr. Cotter to believe that the beds in which they occur and which he has named the 'Yaw stage' correspond in age with the upper eocene of Europe. A paper on the subject, in which he gives a description of some new species of nummulites, appears in the present part of the *Records*.

69. Mr. Bion's work, which was entirely economic, has been referred to under *Gold*.

Central Provinces.

Dr. L. L. Fermor: Korea coalfield.

70. The Central Provinces party during the year consisted of Dr. L. L. Fermor, Messrs. H. Walker, C. S. Fox, R. C. Burton, and Sub-Assistant M. Vinayak Rao. During the earlier part of the year Dr. Fermor was engaged in a detailed examination of the coalfields in the Korea State. The rocks met with there, in addition to those of the Gondwana system, consisted of an Archæan crystalline group and Deccan trap. The crystalline rocks show a striking similarity to those forming the core of the Satpura range in the Chhindwara district, and Dr. Fermor is inclined to regard the crystallines of Korea as merely the extension of the axis of the Satpura range. The representatives of the Deccan trap are chiefly of an intrusive nature and consist of dykes of dolerite of various degrees of coarseness with or without olivine, the most remarkable member of the group, however, being an intrusive sill of very considerable extent occurring immediately to the north of the Kurasia field and partly overlying it. The rock of this sill is coarsely crystalline in the centre, and finer in its upper and lower portions, the margins consisting of basalt from 1 to 3 feet thick.

Mr. C. S. Fox: Chhindwara.

71. Mr. C. S. Fox continued his survey of Chhindwara district, working chiefly in the Chhindwara and Jagir tahsils. The general conclusions arrived at during the previous year were confirmed by the work of the past season, and a considerable amount of new information has been acquired regarding the crystalline rocks which, according to Mr. Fox, fall into three main zones: (1) a zone to the south of the latitude of Lawaghogri, in which the gneisses and schists appear to be obviously older or metamorphosed igneous rocks of granitic character; (2) a zone above Lawaghogri, extending about to the latitude of Chhindwara town and consisting of a group of gneisses and schists of which the origin is obscure. They cannot be regarded as older igneous rocks, nor can they satisfactorily be regarded as of sedimentary origin; (3) the third zone is constituted by a belt, occasionally 8 miles in width, running through Chhindwara town and consisting of coarse porphyritic intrusive granites with which are intimately associated dykes of a medium-grained pink granite, a rock found also in the other zones. Basic rocks are also found in each of these zones

and are represented by diabase, epidiorite and amphibolite. Locally pyroxene is developed at the expense of hornblende.

72. The strike of the foliation throughout these zones is markedly regular, ranging from E. 10° S.—W. 10° N. to E. N. E.—W. S. W., and Mr. Fox is inclined to believe that the country between the Sausar tahsil and the alluvial flats of the Narbada valley now represents the worn-down base of an old mountain system. As regards the Deccan trap, Mr. Fox finds that the trap dykes become more and more numerous as the neighbourhood of the Chhindwara coalfields is approached. The dykes become larger and more continuous, one having been traced for nearly 45 miles continuously and having a width of 30 yards. Information as to the trap-flows of Chhindwara has been made more extensive and more precise; further evidence has been obtained of the overlap on to the crystalline rocks of the last flow but one over the basal flow, whilst an additional, or fifth, flow was observed in the neighbourhood of Changoba at Narsala hill; two more, a sixth and a seventh, apparently existing near Rajdongri; the two last, however, are very thin and their Intertrappean horizons not well marked.

Mr. R. C. Burton: Seoni.

73. Mr. R. C. Burton was engaged on the survey of the Seoni district, the area examined falling roughly into two parts—(1) the trap and laterite plain north of the ghats, and (2) the plain of metamorphic rocks to the south of the ghats. The former plain is approximately 2,000 feet high, and appears to consist of trap-flows covering an old ridge of gneissic rocks forming the continuation of the Satpura range. From the southern edge of the plateau thus formed the ground slopes gradually down to the lower plain consisting of metamorphic rocks with some isolated hills reaching the 2,000 feet level. Amongst the rocks found in the area examined during the season the chief are: laterite, trap, Lameta beds, various forms of gneiss and granite, and a group of rocks, probably of Dharwar age, represented by crystalline limestone, pyroxene gneiss, pyroxenite, amphibolite, quartzite and mica-schist. The laterite is chiefly of the usual high-level type and formed *in situ* by the weathering of the underlying trap. In certain cases, however, Mr. Burton has reason to believe that some of the high-level laterites owe their origin to deposition in a lake basin in the trap, since he has found sandstones interbedded with the laterite. The evidence, however, is not entirely conclusive.

Occasionally beds of lithomarge are found intervening between the laterite and the underlying gneiss or trap. This lithomarge is regarded by Mr. Burton as a product of alteration *in situ* of the rock on which the lithomarge is now found resting.

74. In the *General Report* for the year 1912 reference was made to the discovery by the Central Provinces party of basalt dykes of Deccan trap age traversing the Archæan rocks. Several new dykes of the kind were noticed by Mr. Burton. They fall naturally into three groups, one at Suktara, another at Thanwurjhori, and a third at Katiapar. These were found cutting through both gneiss and trap and are regarded as indicating the position of the fissures through which the Deccan trap was extruded. The only outcrops of Lameta age were found in the neighbourhood of Khammaria, where they consist of beds of sand and sandstone having a maximum thickness of 20 feet and overlying silicified gneiss.

75. From a study of the Satpura range in Seoni district Mr. Burton is not disposed to agree with the statement made by the late Mr. E. J. Jones in *Memoirs, G. S. I.*, Vol. XXIV, to the effect that the small coalfield of Sirgora constitutes practically the eastern edge of the Gondwanas in this area. He rather inclines to the belief that this belt of Gondwana rocks may extend from Chhindwara beneath the trap of Seoni and Mandla, in which case it might be reached by a boring at Lakhnadon. More extensive surveys, however, will be necessary before the probabilities of the occurrence of the coalfield beneath these trap areas can be more clearly estimated.

76. Amongst the older crystalline rocks the silicified and calcified gneisses, referred to in previous reports, were found in several places, being occasionally associated with Lametas.

Sub-Assistant M. Vinayak Rao: Seoni.

77. Sub-Assistant M. Vinayak Rao continued his mapping along the boundary between the Deccan trap and the older crystalline rocks of the Seoni district. Certain areas, which had been only roughly mapped during the previous field season, were re-visited. Mr. Vinayak Rao also records the occurrence of at least six flows of trap.

Kashmir.

Messrs. C. S. Middlemiss and H. S. Bion.

78. During the hot-weather season in Kashmir, several of the new contoured 1″=1 mile degree sheets of the Survey of India became available for delineating the geology. In adjoining areas

where these were not yet ready tracings of the incomplete maps, supplied in advance of publication by the courtesy of the Survey of India, were used with great advantage for field purposes. With the help of these beautifully executed sheets good progress was made by Messrs. Middlemiss and Bion, both in the direction of fresh additions to the revised geological survey now in progress and also in transferring the work of the last few years to these new sheets—checking it where necessary by fresh traverses. Mainly because of the greater attention to detail necessitated by the use of these larger and more accurate maps, the anticipation in last year's report that the valley of Kashmir proper, that is to say, the area within the Jhelum drainage, would be completed this season, has not quite been realised.

The following shows the present state of progress of the survey: —completed, degree sheets 43 J/7 and J/12; mostly surveyed, degree sheets 43 J/3, J/8, J/11, J/16, K/9, N/4, and O/1; partly surveyed, sheets 43 J/4, K/13, together with parts of tracings of 43 K/14, N/8, O/2, O/5 and O/6.

Mr. Middlemiss: Pir Panjal, Kazi Nag, etc.

79. Mr. Middlemiss was mainly concerned in extending the survey to the north-west of the Nil Nag—Tata-Kuti line of section (described *Rec., G. S. I., S.*, Vol. XLI, pt. 2, p. 120) along the Pir Panjal and Kazi Nag (Kajnag) ranges and along the Karewa country fringing the valley of Kashmir at the foot of those ranges. The older series of rocks forming the backbone of the hills is composed of vast thicknesses of Panjal Trap with Agglomeratic Slate below and presumed Gondwanas above. The marine Permian and Trias with their characteristic fossil zones were found to be not continued much beyond the neighbourhood of Tosh Maidan.

80. The Kazi Nag intrusive granite (ordinary Himalayan muscovite-biotite-granite, somewhat foliated) which is also represented by very small intrusive masses on the south side of the Baramulla gorge near Gulmarg, has pierced this old series of rocks, metamorphosing them to phyllites, chlorite schists and epidotised forms of the Panjal Trap with lenticular augen. The north-north-east edge of the Kazi Nag mass appears to be a fault, bringing up locally to the north the older Slate Series along the higher reaches of the Mawar river. These slates present the strange appearance of being less mineralised than the much younger Panjal Trap, etc. The line of this fault is probably co-extensive with that of

the Mahadeo-Nagberan-Aru fault, which elsewhere was simultaneously traced by Mr. Bion, and thus embraces a length of at least 70 miles.

81. The Karewas have afforded unexpectedly interesting features. Chief among these is the further evidence for local lines of sharp folding, with dips of about 40°, which relieve the monotonously regular dip of 18°—20° and even less, which characterises them as a whole, and thus repeats the feature already described at Eosu (Yus, of the new maps) Marg (*loc. cit.*, p. 121). Other features brought to light are the existence of small outlying patches of Karewas at the great height of 11,000 feet, some being actually on the Pir Panjal watershed, and so situated and petrologically constituted that, taking into consideration the dips of 20° of the main mass of the Karewas, the conclusion Mr. Middlemiss finds inevitable is that the Karewas as a whole must have swept in a great arch, varied locally by sharp monoclinal puckers, entirely over the older rocks of the crest of the Pir Panjal before they became all but removed by denudation from the upper part of the arch. It follows that the Pir Panjal range must have about doubled its height by tilting and flexuring since the time when the oak and the alder tree flourished in this region, and became preserved in the Karewa deposits (*loc. cit.*, p. 122). A revised estimate for the total thickness of the Karewas, made possible by the new maps, is 3,000 feet as against 1,400 feet of previous estimates.

82. Although the old grass-covered moraines of the north-east slopes of the Pir Panjal, attributed to the glacial epoch, generally extend to the 10,000 feet level as now determined by the new contoured sheets, they also tail-out down-stream as partially redistributed long processes to as much as 3,000 feet lower (7,000 feet actual altitude), whilst some few very large erratics of Panjal Trap, 18 yards across, are found even at 6,500 feet, as at Arigam village, where owing to the extremely gentle slope of the country no other transport than ice can be imagined as operative.

83. During the latter part of the season Mr. Middlemiss continued the mapping of the neighbourhood of Vernag and the Banihal pass, where during the previous season certain Jurassic fossils were collected by Mr. Bion and himself in a series of limestones, shales and rusty-coloured quartzitic sandstones which follow normally above the topmost Upper Trias beds. The area was completed

so far as the new maps go into connection with the Golabgarh area, with the exception of a small portion south-west of Shupiyan. The well-marked fault between the Banihal pass and Vernag was traced *vid* Kulgam and Shupiyan in a W. N. W. direction to connect up with the Tosh Maidan fault (*loc. cit.*, map and p. 129) and the high-dipping Karewas of Eosu Marg (Yus Marg), a distance of at least 60 miles.

Mr. Bion : tract N. of Srinagar and Pahlgam.

84. Mr. Bion carried out an entirely separate and arduous piece of detailed mapping in the high mountainous region lying to the north of a line joining Srinagar and Pahlgam (Pailgam) and including the Dachhigam State Preserve, the whole of the upper reaches of the Lidar river and the neighbourhood of the famous Kolahoi peak. The rock series involved is a highly complicated folded mass of almost the whole of the fossiliferous series from the Slate Series to the Upper Trias, and is an extension northwards and eastwards of the sequence already mapped and described by Mr. Middlemiss (*Rec.*, *G. S. I.*, Vol. XL, pt. 3, p. 206, with map). As Mr. Bion is putting his work into a form suitable for early publication, it will be unnecessary to do more than indicate briefly a few of the more interesting results that have come to light from the very complete palæontological collections made by him under conditions of considerable difficulty and high altitude. The Agglomeratic Slate series was again found to be fossiliferous at several horizons, the fossils, as in the case of the Marbal valley, being identical with those from the Fenestella Shales. They include especially *Syringothyris Lydekkeri* Dien. and a *Camarophoria* allied to *C. Purdoni* Dav., *Fenestella* and, rarely, *Protoretepora*.

85. With reference to the Lower Trias, Mr. Bion's remarks are of such importance as to be quoted in full. He says: "About 20 feet above the base of the black shales there is a layer of calcareous nodules from which many specimens of *Otoceras* have been obtained associated with almost all the other members of the fauna of the Otoceras beds of the Central Himalaya. Good collections have been obtained from Nagaberan in the Dachhigam State Rakh and from the Pahlgam-Aru basin. Some thirty feet above the Otoceras layer there is another fossiliferous horizon characterised by *Ophiceras* from which one specimen of *Otoceras* was also procured, but the rest of the black shale division seems to

be barren. A surprising element in the fauna of the basal Otoceras layer is furnished by the presence of the genus *Productus*, of which three specimens have been obtained from near Pahlgam. In spite of this Permian element I consider that the fauna of the Otoceras beds of Kashmir has a decided Triassic aspect.

"The black shale division passes up, by a gradual increase in the calcareous intercalations, into some 300 feet of thin-bedded blue limestones which almost invariably break into two well-marked crags. The lower of these crags is absolutely barren, but the upper one, which contains subordinate shales, has yielded fossils. The fauna obtained by C. S. Middlemiss from the Guryul ravine came from these upper beds, and while examining the section at Pastannah from which the same observer obtained his Ophiceras fauna, I was fortunate enough to ascertain that this horizon also occurs in the upper part of these limestones. It now becomes evident that the Guryul ravine fauna is on practically the same horizon as the Ophiceras horizon of Pastannah, a fact strongly at variance with the conclusions arrived at by Professor Diener as a result of his examination of C. S. Middlemiss' collections. Professor Diener referred the Pastannah fauna to the horizon of the Otoceras beds of Spiti and the Guryul ravine fauna to that of the Hedenstrœmia stage of the same area (*Pal. Ind.*, New Series, Vol. V, Mem. I, p. 120). It is now evident that the Pastannah fauna occurs at an horizon some two to three hundred feet above the Otoceras beds proper, and that there is very little difference of horizon between it and that of the Guryul ravine."

In conclusion Mr. Bion is strongly of the opinion that the Pastannah fauna is very nearly allied to that of the Otoceras beds but a slightly different and younger variant, while the Guryul ravine fauna is most nearly allied to that of the Meekoceras beds, as was originally supposed by Mr. Middlemiss.

86. With reference to glacial features, Mr. Bion finds two sets of moraines, the one recently left by the last retreat of the ice, and the other a relic of an older glaciation, the moraines of which are now covered with grass and even small trees. The ice during the older and maximum glaciation certainly reached down to the 8,000 feet level as shown by striated pavements and moraines, and it may well have reached as low as 7,000 feet.

A CARBONACEOUS AËROLITE FROM RAJPUTANA. BY W. A. K. CHRISTIE, B.SC., PH.D. (With text figure.)

THE meteorite here described was presented to the Astronomical Society of India by His Highness Raj-Rana Sir Bhawani Singh Bahadur, K.C.S.I., Raj-Rana of Jhalawar, who supplied the following details to the Society :—

"A very luminous meteor was visible here [Jhālrapātan, 24° 36′ N., 76° 10′ E.], at about 3-55 P.M. on Sunday, the 22nd January 1911. The meteor shot across the northern sky from west to east. It was as bright as a rocket and as big as a cannon ball. The forepart was radiant blue, the middle white, and the back purple. It burst into two on the eastern horizon and gradually got out of sight. A loud and prolonged report like that of thunder followed. It took about five minutes to reach us, and hence the surmise that the meteor burst at a point 60 to 65 miles away from here. The long milky trail left by the meteor rapidly vanished, the sun shining in full glare at the time. . . . . A few weeks ago His Highness the Nawab Sahib of Tonk visited my capital, and in the course of conversation one of his officials told me that on the 22nd of January last a very loud report was heard at Chabra [Chhabra, 24° 39′ N., 76° 52′ E.], at about 4 in the afternoon and was followed by a shower of small pieces of black stone. At my request a few of these pieces were sent to me, for which my thanks are due to His Highness the Nawab Sahib. Some of these pieces I now send to the Director, Meteorite Section."

The fragments were seen by G. H. Tipper, who was then acting as Curator of the Geological Museum, and myself shortly after their receipt by the Astronomical Society; at that time they consisted—with the exception of a number of minute grains weighing in all less than 0·1 g.—of two pieces, the larger of which had a distinct crust with characteristic pittings. When they were presented by the Society to the Geological Survey of India in May 1913, they had to a great extent disintegrated, no crust was recognisable, and small white patches had formed on the surface. The total weight of the meteorite was 7·729 g. The largest

piece weighed 1·7 g.; five others weighed between 0·3 and 0·9 g., and there were innumerable smaller ones totalling 3g. Of these 1·4 g. were finely ground for analysis and 0·23 g. were used for microscope sections.

The analytical results are as follows:—

SiO_2	22·42
TiO_2	0·09
Al_2O_3	1·92
Cr_2O_3	0·12
FeO	22·27
Fe	0·33
Fe (as sulphide)	0·22
NiO	0·86
Ni	0·07
MnO	0·15
MgO	13·71
CaO	1·34
K_2O	0·36
Na_2O	3·24
P_2O_5	0·11
CO_2	0·13
SO_3	6·90
S (as sulphide)	0·13
S (free)	1·44
C	2·70
H_2O (below 106° C.)	10·74
H_2O (above 106° C.)	10·92
	100·17

The water, carbon, silica, total iron, total nickel, alumina, titania, phosphoric oxide, lime and magnesia were determined in one portion. For the estimation of combined water and carbon, the meteorite, dried at 106° C., was heated by a blowpipe Méker burner in a platinum boat in a tube of quartz glass. The oxygen used for the combustion was purified by passage over hot copper oxide, freed from carbonic anhydride by means of caustic potash and soda lime and thoroughly dried with calcium chloride. The gases evolved from the meteorite were passed over heated copper oxide and lead chromate; calcium chloride previously saturated

with carbonic anhydride, was used for the absorption of water, and caustic potash solution and soda lime to take up the carbonic anhydride, the oxygen being displaced before weighing by air similarly purified. The residue after combustion was fused with sodium carbonate and the other constituents determined mainly by the methods recommended by W. F. Hildebrand,[1] all the operations being carried out in platinum or silica glass utensils. The iron, aluminium, titanium, chromium, manganese and phosphorus were separated from nickel, cobalt, calcium and magnesium by three precipitations with ammonia and hydrogen peroxide.[2] (The ammonia was redistilled in platinum over calcium hydroxide, and kept in a platinum bottle.) Iron was estimated with permanganate after reduction with sulphuretted hydrogen; in the same solution titanium was estimated colorimetically and phosphorus precipitated as molybdate and weighed as magnesium pyrophosphate. In the filtrate from the ammonia treatment platinum and any other sulphides insoluble in acid solution were removed with sulphuretted hydrogen, dissolved in aqua regia, the platinum eliminated with formic acid and the remainder tested micro-chemically for copper and tin. No copper was detected, and only a doubtful trace of tin, as rubidium stannic chloride. Nickel, cobalt and zinc sulphides were precipitated with ammonium sulphide free from carbonic anhydride and brought into solution with aqua regia. Nickel was precipitated with dimethylglyoxime; in the filtrate from this precipitation the organic matter was eliminated by evaporation with sulphuric acid, the solution made alkaline with ammonia and electrolysed. The presence of a trace of cobalt on the cathode was shown with ammonium thiocyanate and amyl alcohol. Only a trace of manganese, of the order of 0·00001 g., was found on the anode, showing that the previous separation had been practically complete. Calcium and magnesium were determined in the usual way by double precipitation as calcium oxalate and magnesium ammonium phosphate respectively. The quantities found in 0·1722 g. of the meteorite were 0·0185 g. of moisture, 0·0188 g. of combined water, 0·0173 g. of carbonic anhydride, 0·0386 g. of silica, 0·03075 g. of iron, 0·00015 g. of titanium dioxide, 0·0003 g. of magnesium pyrophosphate (phosphorus), 0·0064 g. of nickel dimethylglyoxime, 0·0023 g. of calcium oxide and 0·0652 g. of magnesium pyrophosphate (magnesium).

[1] *U. S. Geol. Surv. Bull.* 4?? (1910).

[2] M. Dittrich, "Anleitung zur gesteinsaualyse," 14, Leipzig, 1905

The alkalies were determined by Lawrence Smith's method, 0·1141 g. of the meteorite giving 0·0076 g. of the mixed chlorides, from which 0·0021 g. of potassium platinic chloride were precipitated.

The sulphur evolved as hydrogen sulphide on treatment with dilute hydrochloric acid and the carbonic anhydride were determined together in the apparatus figured, by absorption with pumice saturated with partially dehydrated copper sulphate [1] and caustic potash respectively. Nitrogen from a cylinder was freed from oxygen in the aspirator A, in which a muslin bag containing yellow

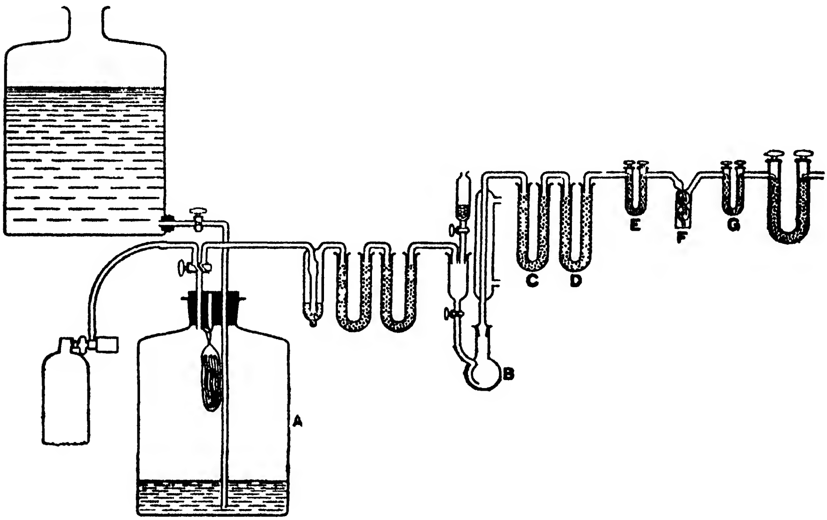

Fig. 1.—Apparatus for determination of hydrogen sulphide and carbonic anhydride.

phosphorus protected from the action of light was hung,[2] and purified by passage through caustic potash solution, soda lime and copper sulphate pumice. A portion of the meteorite having been placed in the flask B, the apparatus was swept out with a current of nitrogen, and the weighed absorption tubes attached.

[1] *Cf.* C. R. Fresenius, *Zeit. f. anal. Chem.*, *10*, (1871), 75, quoted in the same author's "Quantitative Chemical Analysis."

[2] R. J. Strutt, *Proc. Roy. Soc.*, Ser. A, *88*, (1913), 539.

Hydrochloric acid (1 : 3) was then admitted to the flask and boiled in a slow current of nitrogen. The gases after issuing from the condenser passed through two calcium chloride tubes, C and D, and then into the weighed tubes E, F, and G. E was filled to three quarters of its extent with fine copper sulphate pumice, the other quarter at the exit end with calcium chloride. C, D and E had previously been saturated with carbonic anhydride. F contained caustic potash solution and soda lime, G soda lime with calcium chloride at the exit end. The nitrogen was not displaced by air previous to weighing, as the copper sulphide formed is subject to slow oxidation. "Blank" experiments with ferrous sulphide and calcium carbonate showed the method to be reliable. From 0·4449 g. of the meteorite, 0·0006 g. of hydrogen sulphide and 0·0006 g. of carbon dioxide were obtained.

The free iron and nickel, the constituents soluble in water, the manganese and the chromium were determined in the same portion. This was boiled with water in a current of oxygen-free nitrogen in a quartz glass vessel with a ground quartz stopper and two side tubes, and the liquid decanted through a platinum funnel without access of air. After three extractions with water the filter paper was quickly inserted in the quartz vessel and a rapid current of nitrogen passed to remove the air. 20 c. cm. of mercuric ammonium chloride solution, containing 7·8 g. of mercuric chloride and 3·1 g. of ammonium chloride per l.[1] were then added, and the apparatus agitated frequently during 20 hours. The liquid was filtered and the residue washed in absence of air. On gently heating the residue obtained by the evaporation of the aqueous extract to expel water of crystallisation it changed colour from whitish to brownish-black, and at the same time a slight white sublimate was obtained which gave micro-chemical reactions for ammonium. Evidently some of the carbonaceous matter present in the meteorite is soluble in water. The aqueous extract contained a trace of silica; no iron or aluminium was present. Calcium was separated as oxalate and magnesium by the alcoholic ammonium carbonate method of F. A. Gooch and E A. Eddy.[2] The filtrate from the precipitation of magnesium was divided into two equal

[1] *Cf.* C. Friedheim, *Sitz. ber. Akad. Wiss.* Berlin, 1888, I, 346, and H. L. Bowman and H. E. Clark, *Mineral. Mag.* *15*, (1910), 360.

[2] *Am. Jour. Sci.*, Ser. 4, 25, (1908), 444.

parts, in one of which the sulphate was determined, and in the other the alkalies, after removal of the sulphate with the quantity of barium chloride theoretically necessary. From 0·2230 g. of the meteorite were obtained 0·0016 g. of calcium oxide, 0·0010 g. of magnesium oxide, 2 × 0·0195 g. of barium sulphate, 2 × 0·0070 g. of sodium and potassium chlorides and 2 × 0·0024 g. of potassium platinic chloride, equivalent to—

	Per cent.
CaO	0·7
MgO	0·4
K_2O	0·4
Na_2O	3·0
SO_3	6·0
Total soluble in water	10·5

For the determination of free iron and nickel in the mercuric ammonium chloride extract, mercury was removed with hydrogen sulphide, nickel separated from iron by the method of O. Brunck,[1] with dimethylglyoxime in the presence of tartaric acid, and iron, after precipitation as sulphide, estimated with permanganate. In 0·2230 g. were found 0·0008 g. of nickel dimethylglyoxime and 0·0007 g. of iron.

Manganese and chromium were estimated in the residue from the extraction with water and mercuric ammonium chloride. This was ignited and treated with hydrofluoric and sulphuric acids, the former removed by repeated evaporations with the latter, and the slight insoluble residue brought into solution by fusion with potassium pyrosulphate. Manganese was determined colorimetrically in the solution by the method of H. Marshall,[2] a quantity of ferric sulphate equivalent to that present in the solution of the meteorite having been added to the comparison standard. After precipitation of the silver as chloride and the platinum as sulphide, the solution was evaporated to dryness in porcelain; the residue was ignited, fused with sodium carbonate in porcelain, leached with water, and the chromium determined colorimetrically. In 0·2230 g. of the meteorite 0·00034 g. of manganous oxide and 0·00027 g. of chromic oxide were found.

[1] *Cf. Zeit. anal. Chem.*, *47*, (1908), 167.
[2] *Chem. News*, *83*, (1901), 76.

The free and combined sulphur were determined in another portion weighing 0·1809 g. This was ground with hot chloroform in a platinum basin, the liquid decanted after 24 hours, and the extraction repeated four times. The total sulphur in the unattacked residue was determined by the method of G. Lunge.[1] That no sulphur remained in the part insoluble in aqua regia was shown by fusion with sodium carbonate. 0·0380 g. of barium sulphate were obtained, corresponding with 6·97 per cent. of sulphuric anhydride, after the deduction of the sulphur present as sulphide.

The chloroform extract, on evaporation at ordinary temperature, deposited long yellow crystals of sulphur with straight extinction and high polarisation colours. The extract was dried at 106° C. and weighed then 0·0045 g. The presence in the meteorite of a carbonaceous substance soluble in water having been ascertained during the analysis of the water-soluble constituents, the chloroform extract was treated with boiling water to separate it. This aqueous solution was evaporated and the residue dried at 106° C. It weighed 0·0009 g. It consisted of two substances, one white with a dendritic habit, doubly refracting, changing colour to a greyish brown on heating, the other, yellowish white globules, whose cryptocrystalline structure was indicated by the presence in each of a black cross between crossed nicols in plane polarised light. These globules were less soluble in water than the dendritic substance and, when heated, became opaque and dark brown in colour. The minute quantity of material available precluded further characterisation.

The portion of the chloroform extract which was insoluble in water (0·0036 g.) did not consist entirely of sulphur. It was brought into solution by the method of E. Berger[2] and the sulphur precipitated as barium sulphate. 0·0190 g. were found, equivalent to 0·0026 g., or 1·44 per cent. of sulphur. The remaining 0·0010 g. is considered as carbonaceous material.

The accuracy of the analytical figures as a guide to the true composition of the meteorite suffers from the paucity of the material available for analysis and also from its by no means

[1] G. Lunge and E. Berl, "Chemisch-technische Untersuchungsmethoden," 6th ed., 1910, 1, 323.

[2] *Comptes Rendus*, *143*, (1906), 1160.

unweathered condition. There are other defects in the analysis, the chief of which are the absence of direct determinations of the ratio of ferrous to ferric iron and of the hydrogen (and oxygen, if any) present in the carbonaceous constituents. The indeterminate extent of the reducing action of the bodies containing carbon rendered the former estimation unfeasible; the hydrogen has been included in the "H_2O (above 106° C.)." The errors entailed have probably counterbalanced one another in the summation.

Though no chondritic structure was apparent in the imperfect slides prepared, the meteorite should be classed as K (coaly chondrite) in A. Brezina's classification.[1] In O. C. Farrington's quantitative classification [2] it would appear in the Jeromose group, for, deducting the materials soluble in water, the carbon, the sulphur and the water, its norm is "perfemic, persilicic, perpolic, perolic, permirlic, permiric, magnesi-ferrous."

Under the microscope the meteorite appears as a structureless, irregularly cracked mass, varying in colour from dark brown to black, and in lustre from vitreous to dull. Small white patches with tufts of acicular crystals had formed promiscuously on its surface.[3] These were not apparent when the meteorite was received by the Astronomical Society and had developed subsequently to its fall. Some of these minute crystals, with a refractive index of 1·52 and oblique extinction, were very slowly soluble in water and gave micro-chemical reactions for calcium and sulphate. Besides gypsum, however, magnesium sulphate was also detected in the white specks.

On account of the friable nature of the material it is difficult to obtain a very thin section. One 0·02 mm. thick showed little trace of any structure, but consisted of an opaque, amorphous, mottled mass, varying in colour from dark brown to black, with specks here and there of an indeterminable, lighter brown, doubly refracting mineral. Small patches of glassy material with phenocrysts probably of quartz and a rhombic pyroxene could

[1] *Ann. K. K. nat. Hofmuseums*, Wien, *10*, (1896), 254, and *Proc Am. Phil Soc.*, *43*, (1904), 237.

[2] *Field Mus. Nat. Hist.*, Chicago, Geol. Ser. 3, No. 9, 195, *et seq.*

[3] The formation of such growths on meteorites of the coaly chondrite group, to which the Tonk aërolite belongs, seems to be characteristic of the class. Of the nine known members of the group seven are represented in the collection of the Geological Survey of India,—Alais, Cold Bokkeveld, Kaba, Mighei, Nawapali, Orgueil, and Tonk—and each of these has a crystalline efflorescence,

be discerned with a $\frac{1}{10}$ inch objective. One comparatively large, lozenge-shaped crystal (about 0·3 mm. long) was present in the slide. Its strong double refraction, double system of cleavage cracks intersecting at about 65°, the direction of extinction being nearly parallel to the diagonals of the cleavage rhombs, were reminiscent of calcite; such vestiges of a figure as were obtainable in convergent light did not, however, indicate uniaxial symmetry and on removal of the cover-slip the mineral did not dissolve in concentrated hydrochloric acid.

On account of the porous nature of the meteorite and the presence of sulphates soluble in water and of sulphur and carbonaceous matter soluble to some extent in most organic liquids, the determination of the specific gravity presented difficulties. The paucity of material and the fact that such fragments as might be used in a determination by any immersion method would be thereby rendered useless for other purposes, led E. P. Harrison and S. N. Ghose[1] to ascertain the density by means of a volumenometer. The limits they assigned were 3·8—4·4. As their figures differ widely from those recorded below, the procedure followed is given in some detail. The ordinary method of displacement was employed, the liquid used being kerosene oil, from which the lighter fractions, boiling up to 140° C., had been distilled. A fragment of the meteorite, which, after being dried at 106° C., weighed 0·1698 g., was placed in a small dish of platinum foil to which were welded two platinum wires of 0·05 mm. diameter united above the dish to a single strand ending in a loop. The apparatus weighed in air 0·1066 g., and immersed in the oil to a mark on the wire, 0·1030. The apparatus with the meteorite fragment was suspended in kerosene from a hook passing through the cork of a pressure flask, which was then exhausted to a pressure of less than 1 mm. of mercury to remove occluded gases. Without removal from the flask, the combined mass of the fragment and the apparatus immersed in kerosene to the mark on the wire was ascertained to be 0·2178g. The density of the oil being 0·8119, the specific gravity of the specimen is $\frac{0\cdot1698-(0\cdot2178-0\cdot1030)}{0\cdot1698}\times$ 0·8119, *i.e.*, 2·51. The small mass of the specimen and the not inappreciable solubility in kerosene of its contained sulphur militate against the accuracy of the estimation, the latter factor, of course, tending to make the observed specific gravity greater than

[1] *Jour. Astron. Soc. Ind.*, 3, (1913), 105.

the true value, but it may certainly be taken as correct to the first place of decimals for this particular specimen. A check determination was made with two minute fragments, which, after being dried at 106° C., were placed in the horizontal limb of a bent tube attached to the pump. The other limb was closed and the tube exhausted for two hours. A test-tube containing Thoulet's solution of density 2·49 was then attached to the vertical limb of the tube and after exhaustion the apparatus was tilted to allow the fragments to drop into the solution. Neither showed any tendency to sink, until after many minutes, when the solvent action of the solution on some of their lighter constituents raised their density above 2·49.

The chief interest of the Tonk meteorite lies in its highly carbonaceous character. The only other known meteorite with a greater percentage of carbon is Alais, with 3·36 per cent.[1] Two other stones, Orgueil and Mighei, may contain more, but the analytical data are conflicting in the one case [2] and incomplete in the other.[3] The composition of the carbonaceous matter is very uncertain. 0·5 per cent. of the stone consists of matter soluble both in chloroform and in water, and described on p. 47, while there is a similar quantity soluble in chloroform and insoluble in water, whose separation from sulphur was not effected. Even if we assume that these bodies contained no smaller proportion of carbon than is represented by the formula C_nH_n (they could not contain less), there is still 1·7 per cent. of carbon unaccounted for. This is not present as graphite, no trace of which could be detected as graphitic acid.[4] The high percentage of water obtained from the meteorite on combustion in oxygen might suggest the derivation of part of it from hydrogen present in combination with the carbon as "coaly" material insoluble in chloroform. It is, however, quite probable that the olivine to which the meteorite closely approaches in general composition (it accounts for over 80 per cent. of the "norm" of the siliceous constituents, although its presence is not evident in thin sections) may, on account of the very porous nature of the material, have weathered to some extent to serpentine, absorbing a considerable proportion of water, which would not be driven off at 106° C.

[1] H. E. Roscoe, *Proc. Lit. Phil. Soc.* Manchester, *3*, (1864), 59.
[2] S. Cloez, *Comptes rendus*, *59*, (1864), 37; Pisani, *ibid*, 132.
[3] S. Meunier, *Comptes rendus*, *109*, (1889), 976.
[4] *Cf.* W. Heinisch, C. Doelter's "Handbuch der Mineralchemie," Leipzig, 1912, I, 59.

There is more free sulphur in this aërolite than in any other of which I have found data. It was assumed in estimating its percentage that the organic matter extracted with it by means of chloroform, and insoluble in water, contained no sulphur in combination. It was not found possible to test this assumption; were it unfounded, the sulphur organically combined would have to be deducted from the total reported as "free."

The other components of the stone present no abnormal features.

It would have been preferable to name this meteorite "Chhabra" after the exact locality of its fall; the name "Tonk," the Native State in which Chhabra is situated, has, however, already been used for it by E. P. Harrison and S. N. Ghose [1] in their paper on its density, and is therefore adopted.

[1] *Loc. cit.*

NOTES ON THE VALUE OF NUMMULITES AS ZONE FOSSILS, WITH A DESCRIPTION OF SOME BURMESE SPECIES. BY G. DEP. COTTER, B.A. (DUB.), F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 1—3.)

1. On the value of Nummulites as Zone Fossils, with notes on the Orbitoides.

Introduction.

LAST winter (January to March, 1913) I collected some interesting varieties of nummulites in Burma, from an area west of Pauk, a small town which is the headquarters of the Pauk sub-division of the Pakokku district. The area lies between latitudes 21° 15′ and 21° 30′; and between longitudes 94° 15′ and 94° 25′. It is traversed by the Yaw river, one of the principal tributaries of the Irrawaddy south of its confluence with the Chindwin river. The sections exposed in the Yaw west of Pauk are peculiarly interesting. Near Pauk the Irrawaddy series (age probably Pontian-Pliocene) is exposed; underneath this is a series of beds, mainly sandstones, with very poorly preserved fossils, which must be in the main an estuarine or fluviatile facies of the Pegus. Below this is a well-marked highly fossiliferous zone, mainly shale, which I have termed the Yaw stage, and which I regard as upper Eocene. The term Yaw stage has I believe been used previously by geologists in Burma to indicate this horizon, but I cannot find any mention of it in any published paper, although the section has been alluded to by E. H. Cunningham Craig (**35**, p. 16) who mentions the term "Yaw Sandstone Group." This term "Yaw Sandstone Group" does not appear to be synonymous with mine, since it apparently applies to a series of oil-bearing sandstones which immediately underlie the shale-zone which I have termed the "Yaw stage."

E. H. Cunningham Craig (**35**, p. 31) includes these oil-bearing sandstones (and the shale zone above them to which I have given the name of Yaw stage) in the Pegu series. I am of opinion, however, that this horizon is an Eocene one, and that it should be included in the Nummulitic or Eocene series rather than in the Pegus. In order to decide the question of the age of these beds, I have been led to a detailed examination of their included fossils. The results obtained from an examination of the mollusca will form the subject of another paper.

This present paper will deal with the nummulites collected from the Yaw stage, prefaced by a discussion on the value of nummulites as zone fossils.

Preliminary Remarks.

The nummulites which I have collected are allied to the species *N. aturicus* and *N. scaber*. Before proceeding to their description, it will be necessary to discuss at length the value of nummulites as zone-fossils, since several important geological problems can be solved only by a careful consideration of this question.

In a previous paper (**1**) I have noted the presence of the following foraminifera from the Eocene of Burma: *Nummulites beaumonti* D'Arch., *N. vredenburgi* Prever, *Orthophragmina omphalus* Fritsch, *Gypsina globulus* Reuss.

From a consideration of both the foraminifera and the mollusca I regarded this fauna as Lutetian, or Khirthar in terms of Indian nomenclature.

The fauna of the Yaw stage shows affinities both with those beds which I have already classed as Khirthar, and with some beds exposed in the north of the Minbu district near a stream called the Zaha Chaung. H. Douvillé (**2**), however, regards these latter Zaha Chaung beds as probably Bartonian.

The Yaw stage has, however, as we have seen, been regarded as part of the Pegu series by Cunningham Craig rather than part of the Eocene of Burma. The difficulties in correlating the various sections of Burma have led to a consideration of the boundaries of the Khirthar and Nari (Eocene and Oligocene) of India, and of the correlation with the Eocene of Java, the foraminifera of which have been described by Verbeeck and Fenemma (**3**).

Similar difficulties in correlation have arisen in Europe, and conflicting views have been put forward; I therefore propose to give in this paper both a résumé of the views of European geologists on the distribution of nummulites in the Eocene and Oligocene, and a discussion of such evidence as can be obtained from India, Burma, Java and Borneo.

Is the boundary of the Pegus and Eocene unconformable in Burma?

Field-work in the Minbu district (**1**) and in the Ngahlaingdwin area has not revealed the presence of unconformity between the Pegu and Eocene series. In the Yaw section of the Pakokku district, which will be frequently alluded to in this paper, the Pegus are in the main brackish or fluviatile deposits, while the Yaw stage underlying them is marine; the Pegus themselves are marked by current-bedding, and most probably are rull of local unconformities.

It has been thought that an unconformity similar to that described by E. Vredenburg (**5**, p. 89) as existing in North-Western India between the Nari and Khirthar stages might be found in Burma, but field-work has not substantiated this view in its entirety, and while I should be the first to assert that there are numerous local unconformities throughout the Pegu series in Burma, I am of opinion that beds which are missing in one section are to be found in others, in such a way that we cannot draw any one horizontal line of unconformity dividing the series.

The Borneo Deposits.

The hypothecated unconformity between the Nari and Khirthar stages of India represents the absence of the Priabonian (Bartonian-Ludian) stage of Europe. This period according to H. Douvillé (**2**) appears to have been a period of deposition in Borneo. This authority describes beds of Bartonian and Sannoisian (Latdorfian) ages, the former beds being characterised by *Orthophragmina*, and the latter by *N. sub-Brogniarti* which he informs us is probably a race of *N. intermedius*, and is represented in India by *N. sublævigatus*. There are no lepidocyclines in these beds.

The fauna of the Lutetian of Borneo contains *Orthophragmina omphalus* and a small nummulite resembling *N. biarritzensis*. Also there is present a variety of *Orthophragmina papyracea* (Verbeeck's avr. *javana*).

The Java Eocene is especially interesting, and it will be necessary to discuss it in detail. Verbeeck and Fennema (**3**, p. 1183) divide the Java Tertiaries into Eocene, Oligocene and Upper Tertiary. The foraminifera from these three divisions, as given in their table which includes some species from Borneo, are :—

The Java Eocene.

Eocene :—*Alveolina javana*, *Nummulites javanus*, *Baguelensis*, *Assilina spira* and *Leymerii*, *Orthophragmina papyracea minor*, *ephippium*, *dispansa*.

The fauna of the Oligocene is :—

Alveolina sp., *Nummulites lævigatus*, *Nanggoulani*, *Joguiakartæ*, *Pengaronensis*, *sub-Brogniarti*, *biarritzensis*, *striatus* var. *f.*, *Orthophragmina papyracea* and *dispansa*.

The fauna of the Upper Tertiary is :—

Alveolina spp. *Orbitolites Martini*, and various lepidocyclines.

In view of more recent work, it is obvious that these stages can no longer be assigned to the ages attributed to them by Verbeeck and Fennema. It is readily seen that the fauna of the so-called Oligocene is largely an Eocene fauna. E. Haug (**4**, p. 1517) calls it Priabonian, while attributing a Lutetian age to the Eocene fauna of Verbeeck and Fennema. Probably as my colleague Mr. Vredenburg has pointed out when reading the proofs of this paper, the so-called Oligocene fauna represents a mixture from different horizons. This supposition is supported by the consideration that Verbeeck and Fennema have included in their table four species from Borneo, namely, *N. sub-Brogniarti*, *N. pengaronensis*, *N. biarritzensis*, and *N. striatus* var. *f.* As we have seen above, the Borneo beds containing the first of these species are attributed by H. Douvillé to the Sannoisian. *N. sub-Brogniarti* is the only one of these species which Verbeeck and Fennema have recognised in Java, as regards the other three these authors remark (**3**. p. 1155) in their description of the limestone containing *N. sub-Brogniarti* :—"This limestone contains other nummulites strongly resembling those of Borneo, but they could not be identified with these with certainty." The limestone referred to is from the valley of Soukarama in Preanguer, while in the list given above the other species of the "Oligocene" (*N. lævigatus*, *Nanggoulani*, *Joguiakartæ*, *Orthophragmina papyracea* and *dispansa*)

come from Nanggoulan. On p. 577 of their work, Verbeeck and Fennema correlate the limestone of Preanguer containing *N. sub-Brogniarti* with the Nanggoulan beds containing *N. lævigatus* in the following words :—" The nummulites contained in this limestone are different from the usual Eocene forms of Java, but resemble those of stage γ of Borneo, the oligocene age of which is probable. The alveolines themselves are not analogous to those of the Eocene beds of Baguelen. As elsewhere the limestone is interposed between quartzose grits and beds incontestably Miocene; we consider it as the representative of the area of Nanggoulan in Joguia, and we have coloured it as Oligocene on the map." This correlation with the Nanggoulan beds is perhaps unsound. While the limestone of Preanguer may reasonably be Oligocene, the fauna of Nanggoulan appears to be so typically Lutetian, that we cannot correlate the two without upsetting the usually accepted views regarding the ranges of *N. lævigatus* and *N. sub-Brogniarti*. The age of the Nanggoulan beds is discussed by Verbeeck and Fennema on pp. 356-357 of their book, and it is clear from such remarks as " Toutefois, par la présence d'orbitoïdes, les couches de Nanggoulan ont une grande ressemblance avec les couches éocènes" that they were by no means confident of the Oligocene age of these beds.

Messrs. R. B. Newton and Holland (**28**) discuss the relationships of the Javan *N. lævigatus*, which although differing from the typical European species, is nevertheless as closely related to the type as that found in the Bracklesham Beds, whose lower division is of Lutetian age.

We may for the present omit to lay stress on the presence of *N. sub-Brogniarti*, which H. Douvillé regards as identical with the Indian species *N. sub-lævigatus* and a race of *N. intermedius*, and note that, with the exception of this species, and omitting the three other Borneo species above mentioned, the Javan so-called Oligocene fauna under discussion is essentially Lutetian. I give below two tables showing the zonal distribution of Nummulites in Europe after H. Douvillé and J. Boussac as given in E. Haug's Traité de Géologie (**4**, p. 1421) and in India after E. Vredenburg (**5**). A careful examination will reveal certain interesting differences between the two tables.

Comparison of Indian Nummulite Zones with those of Europe after J. Boussac.

Vertical Distribution of Nummulites after H. Douvillé and J. Boussac.

	Radiate Nummulites	Reticulate Numm.	Assilines.
Rupelian . .	N. Bouillei-Tournoueri.	N. intermedius-Fichteli.	
Latdorfian . .	N. vascus-Boucheri.	N. intermedius-Fichteli.	
Ludian . .	N. Bouillei-Tournoueri.	N. Fabianii.	
Bartonian .	N. Bouillei-Tournoueri. N. contortus-striatus.	N. Fabianii	
Auversian .	N. contortus-striatus. N. Heberti-variolarius.	N. Brogniarti. N. aturicus-Rouaulti	 A. exponens.
Upper Lutetian	N. atacicus-Guettardi. N. irregularis	N. Brogniarti. N. lævigatus. N. aturicus-Roualti. N. complanatus, gizehensis.	 A. granulosa A. exponens.
Lower Lutetian	N. atacicus . . N. irregularis.	N. lævigatus-Lamarcki.	A. spira.
Londinian . .	N. elegans-planulatus.		
Thanetian . .	N. Spileccencis-bolcensis (?).		

Table showing the Zonal Distribution of Indian Nummulites, after E. Vredenburg.

		Radiate Nummulites.	Reticulate Numm.	Assilines.
Pegu or Mekran Series.	Beds with small Lepidocyclines.	N. Niasi.		
	Beds with *L. marginata*. (Gaj.)	N. makullensis.		
	Beds with *L. dilatala*.	N. vascus . .	N. intermedius.*	
	Beds without Lepidocyclines.	N. contortus (?) .	N. intermedius.*	
Upper Khirthar .	Zone 4 . .	N. biarritzensis (?)	N. Brogniariti (?)	
		N. Variolarius (?)		
	Zone 3 . .		N. complanatus.	
	Zone 2 . .		N. perforatus.	
	Zone 1 . .		N. perforatus .	A. spira.
Middle Khirthar .	B . . .	N. Beaumonti, Murchisoni, discorbina.	N. perforatus, lævigatus.	A. spira, exponens.
	A . . .	N. discorbina	N. Douvillei, gizehensis. N. perforatus, lævigatus.	A. exponens, sufflata.
Lower Khirthar .		N. irregularis .	N. perforatus, N. lævigatus.	A. exponens.
Laki Stage . .	Ghazij Beds .	N. irregularis, N. atacicus.		A. exponens, granulosa.
	Alveolina Limestone.	N. irregularis, N. atacicus.		A. granulosa.
	Meting Shales .	N. atacicus .		A. granulosa.
Upper Ranikot Stage—	4 . . .	N. planulatus .		A. miscella.
	3 . . .			A. miscella.

* NOTE.—The sp. here tabulated as *N. intermedius* is D'Archiac's *N. Sub-lævigatus*, while the *N. irregularis* of the Laki stage represents a "variety somewhat intermediate between *N. planulatus* and *N. irregularis* type." (5, p. 87) G. deP. C.

The table showing the distribution of Indian Nummulites has been arranged in the same manner as the European table, in order that comparison may be more easily effected. It is first to be noted that the Laki stage is characterised by four species, *N. irregularis*, *N. atacicus*, *A. granulosa*, and *A. exponens*. It should therefore be referred (assuming the accuracy of J. Boussac's table) to the Upper Lutetian, at which horizon only, these four species are found together. Again the presence of *N. lævigatus* and *A. spira* in the middle Khirthar renders it necessary to refer the Middle Khirthar to the Lower Lutetian, at which horizon only these two species are found associated, if the European table be correct.

We should therefore at first sight arrive at the absurd conclusion that the Khirthar is older than the Laki. But we must analyse the discrepancy further.

Of the species above mentioned *N. lævigatus*, *N. atacicus* and *N. irregularis* need not concern us, since these species are common both to the upper and lower Lutetian. The most serious difference between the two tables lies in the different ranges of the species *A. granulosa* and *A. spira*. It must be remembered that the table given by E. Vredenburg represents actual occurrences while that given in E. Haug's text-book is a generalised one. It would, therefore, be unjust to assume that zone 2 of the Upper Khirthars is Auversian from the presence of *N. perforatus* (*aturicus*, *crassus*) unaccompanied by Lutetian forms, because the typical Lutetian form *N. complanatus* occurs above, and might theoretically occur also in zone 2. If the queried identification of *N. contortus* in the lowest stage of the Mekran series were correct, a horizon not newer than Bartonian would be indicated. An imperfectly preserved specimen might however be indistinguishable from the Oligocene derivative of *N. contortus*, *viz.*, *N. miocontortus*, although they are easily separated if well preserved. As any rate it would be contrary to the table given in E. Haug's text-book to suppose that *N. contortus* and *N. intermedius* could occur together. The Indian species which E. Vredenburg here tabulates as *N. intermedius* is that described by D'Archiac as *N. sub-lævigatus*, a form which as we have seen is regarded by H. Douvillé as identical with *N. sub-Brogniarti*. Curiously enough we find a somewhat similar state of affairs in Borneo where in Verbeeck's stage (γ)

(**3**, p. 1155). *N. sub-Brogniarti* and *N. striatus*, the megaspheric form of *N. contortus*, were supposed by Verbeeck to co-exist. I may remark that D'Archiac in his monograph distinguishes *N. intermedius*, which he classes with his reticulate group of nummulites, from *N. sub-lævigatus*, which latter species he refers to his group of sub-reticulates. Taking into account the close resemblance between *N. intermedius* and *N. Fabianii* Prever, which last was not finally and clearly separated from *N. intermedius* by means of good photographs and description of its external characteristics until the appearance of J. Boussac's description in 1906 (36), it is possible that there may be among the numerous varieties of *N. sub-lævigatus* in India and among the specimens of *N. sub-Brogniarti* from Borneo, some which are referable to *N. Fabianii* rather than to *N. intermedius*. Should this be the case and should the queried occurrence of *N. contortus* prove correct, it would point to a slightly older age than Oligocene for the basal beds of the Nari stage of the Mekran series. Although the want of correspondence of the zones of *A. spira* and *A. granulosa* need not be discussed in detail for our ensuing argument, yet it is interesting to notice that according to De La Harpe these species are absent from the Egyptian Eocene. De La Harpe (**29**, p. 212) says:—" D'Archiac in his Monograph (p.p. 6 and 153) mentions *Assilina granulosa* from Egypt, to which he refers in a note in his 'Histoire du progres de geologie' (Vol. III, p. 207) in which it is noted that the small ammonites cited by Gaillardot (Annales de la société d'émulation des vosges, vol. V, p. 703, 1845) and also the small fossils which he had observed in an unfinished work on Egypt, probably belong to *Nummulites spira* var. *a.* Also Fraas (Aus dem Orient, 1, p. 131) derives *N. spira* from Beni Hassan, whereas the fossil marked with this name in the Stuttgart Museum is a large *Operculina* and not an *Assilina.* Furthermore I have not seen in any collection of Egyptian fossils either *A. spira* or *A. granulosa,* therefore I conjecture that both the small Ammonites of the group of Arietes cited by Gaillardot and also both Assilines cited by D'Archiac merely remain to be removed to *Operculina.*" In Java *A. spira* occurs in the lowest of the three divisions given above—a position more in accordance with the European table than that of its Indian representative.

Neglecting the queried identification of *N. contortus*, it will now be evident that the two tables mutually support each other

excepting in the following respects, (1) the Indian table gives no reliable information concerning the Bartonian-Ludian period, and (2) the Assiline zones do not correspond.

I cannot now enter into a discussion of the relationships of *N. sublævigatus* and *N. sub-Brogniarti* with *N. intermedius*, *N. Fabianii* and other closely allied forms, but would remark that the evidence of these nummulites alone must be very cautiously sifted before we assign the beds in which they occur to a particular stage and one stage only. We have seen that a limestone containing a form identical with *N. sublævigatus* (*N. sub-Brogniarti*) has been correlated by Verbeeck and Fennema with beds containing *N. lævigatus* and *Orthophragmina papyracea* var. *javana* in Java, and that the Javan beds are referred by E. Haug to the Priabonian, while the *N. sublævigatus* beds of India are regarded as of later age. Either the nummulites have an unprecedented range in this area or else considerable confusion has arisen.

The Nari-Khirthar Unconformity.

Before I proceed to discuss further the evidence from the various sections in Europe, I wish to point out some of the difficulties in the way of accepting the theory of a wide-spread unconformity embracing practically the whole of the Priabonian (Bartonian-Ludian) period in North-West India and Baluchistan. The alternative theory which I put forward in its place is to suppose that the absence of the "Priabonian" in India is partly the absence of a facies, and does not indicate a long time interval. On the former theory, we must suppose that there was a period from which no deposits have survived over the whole of North-West India. Probably a similar conclusion, if we do not modify our views on the zonal distribution of nummulites would be found necessary in Java. A similar unconformity must be recognised in Madagascar (**4**, p. 1514) and in many other areas, with perhaps the exception of Borneo. A similar state of affairs exists in very many European areas, where deposits of "Priabonian" age are rare. It is difficult to perceive why at a certain period there should be no deposition over such widely separated areas. What has become of the deposits of Priabonian times in Asia? Presumably deposition proceeded in this as well as in other periods of the Earth's history, and some substantial remains of those deposits ought to be expected.

The boundary of the Naris and the Khirthars is described in the 2nd edition of the Manual of the Geology of India (**37**, p. 308) in the following words:—"The present sub-division" (*i. e.*, the Naris) "comprises at its base the uppermost bands of limestone containing *Nummulites*, the species *N. garansensis* and *N. sub-lævigata* being distinct from those so commonly found in the Khirthar sub-division, and the limestone itself is usually distinguished by its yellowish brown colour, and by being in comparatively thin bands, interstratified with shales and sandstones. Several other fossils besides the nummulites, differ from those in the Khirthar beds. Not infrequently however there is an apparent passage from the white or greyish white Khirthar limestone into the yellow or brown Nari rock, and the two groups appear always to be perfectly conformable, but no intermixture of the characteristic species of nummulites has been detected, and the division between the Khirthar and Nari beds can always be recognised by the fossil evidence."

In Burma I have been unable to find any one line of unconformity dividing rocks of Nari from rocks of Khirthar age. May not the time-interval between the deposition of the highest bed of the Khirthars and the lowest of the Naris be much shorter than has been supposed, or must we admit that the evidence of foraminifera definitely settles this question in the negative?

A. Heim's memoir on the Swiss Alps.

Recently Dr. Arnold Heim of Zurich has published a most important memoir (**6**) which must, if his views prevail, seriously modify the whole question of the value of Nummulites as zone-fossils for the purposes of comparison of different areas. His conclusions have been, and I believe are still being, vigorously contested by J. Boussac and are not accepted by H. Douvillé. Several papers have been published on this subject both by Boussac and Heim in the Bulletin of the Geological Society of France (**7, 8, 9, 10**).

Dr. Heim's view is briefly stated in a paper in the above-mentioned journal (**7**, p. 28); this passage I will quote. In this and other passages which I am about to quote in the course of this paper, I have translated the words into English.

Dr. Heim says :—

"In lieu of classing the geological stages and sub-stages after their nummulites, and of saying accordingly that nummulites are valuable fossils for the establishment of synchronisms, I have been led to say in preference that nummulites are not valuable fossils for the establishment of synchronisms. ....This then is my view of the question— the Nummulites are —at least in the Swiss Alps— *stenopic* fossils, that is to say, they depend more or less upon lithological facies. As the facies changes to a more neritic type, *Assilina exponens* disappears ; nearer the shore and the mouths of rivers *N. complanata* disappears in the same way, and there remain only "small nummulites" (*N. striata, Fabianii, variolaria, Boucheri,* etc.). One must then be very careful not to take two zoological provinces for two different stratigraphical stages. I am far from denying the possibility that the same lithological horizon can change gradually in age from one point to another. To demonstrate that a given bed changes in age in its horizontal extension, one must have absolute proofs instead of hypotheses based upon the evolution of nummulites, such as one wrongly admits to-day. A change of even the whole fauna in no way implies a difference in age of two distant points of the same bed. In the Swiss Alps one cannot recognise the Bartonian or younger fauna, but there exist two provinces with different faunas of the same Lutetian age. The facts then oblige me to say without hesitation that the "Priabonian" beds of Diablerets are not above, but 1,000 2,000 metres below the Einsiedler Beds."

J. Boussac (**9**) replies to this in a paper in which he discusses the several sections containing *N. Fabianii* and "small nummulites," and shows that these Priabonian beds are in no section overlain by beds containing Lutetian species, nor associated in the same bed with Lutetian species. He contends that the Flysch Group or the Einsiedler beds may be Lutetian, Auversian or Priabonian in different points ; accordingly the Pilatus beds which underlie them and which according to A. Heim contain in some sections *N. complanatus*, and in others *N. Fabianii*, may also be of different ages.

For the sake of clearness, I give below an abridgement of A. Heim's correlation table facing p. 140 of his memoir (6).

GESTEINSGRUPPEN.		ZEITABSCHNITTE.	ZEITSTUFEN.	Flibachgebiet bei weesen Axendecke ?	Schlossberg-Engelberg. Titliskette ; autochthon.	Waldegg-Habkern a. Thunersee. (obere helvetische Decken.)	Diablereta.
ob. Flysch (k) = obwoldner sch. K.		Ober Eocene?	Bartonien-Ludien.				
Flysch-Gruppe.	unterer Flysch (Kaufm.) Einsiedlerschichten.	Mittel Eocen.	oberes Lutétien (—Auversien ?)	400 m. grunlich gran Mergel......mit *N. distans*, *A. granulosa*, *O. Archiaci.*		Wildflysch schwartzer schiefer mit sandsteinlagen, Fucoidenschiefern, Nummulitenkalken und exotischen Blöcken.	
				ca. 200 m. Im Mergelschiefer mehrere Lagen von Numm. kalk und Grunsand mit *N. Gallensis*, *A. exponens*, *O. discus.*	Sandsteine und Dachschiefer mit Glarnerfischen Taveyannazgruppe 100—150 m	Graue Globegerinenschiefer mit Einlagerungen von Lithothamnienkalk.	Schiefer und Sandstein — Dachschiefer ??
				gelblicher Mergelschiefer mit Globigerina ca. 60 m	graue Mergelschiefer mit Sandsteinbänken ca. 70 m	*Assilina*, *N complanata*, *irregularis Actinocyclina stellata*, *patellaris*	" Schistes grisjaunatres " mit Fucoiden und Taveyannaz sandstein.
Pilatusschichten (Kaufm.)	obere Pilatusch. Hohgantschichten			glimmer sandige schieferige Mergel 1+? m.	einige m mergelige Sandsteine mit Pektiniten	Hohgantsandstein mit Einlagerungen von Schiefer (Pectenitenschiefer) und Nummuliten kalk *N complanata* *N " perforata," O discus. Echinolampas affinis.*	" schiste nummulitique superieur " z t mit kleinen Nummuliten- (Ubergangs-schichten).
	Untere Pilatusschichten oder Bürgenschichten		mittleres Lutétien	mergelige Kalkbänke im oberen Teil steril (2)—8 m	mergeliger Sandstein kalk mit Orthophragminen und Lithothamnien 7 m *N. striata, Heeri.* massiger Quartz-sandstein z T kalkig mit *Orthophr.* und *N. Fabianii.*	Sandige Übergangs-schichen Haupt complanata-kalk voll *N. complanata, O discus.*	Calcaire a petites Nummulites *N contorta, Murchisoni, Fabianii* Gres nummulitique 45 cm.
				tief grüner fein-kornige Glauconit kalk " Assilinengrunsand " voll. *A. exponens, O discus,* seltener *N. complanatus.*	1—2 m flaseriger Mergel kalk und Mergel bitumbnös abfärbend = Cerithien schichten.		Couches à Cérithes Miliolites, *Cerithium Diaboli*, reiche Molluskenfauna 32 m.

This extract represents only a small portion of A. Heim's correlation table, nevertheless we may observe how he correlates the famous "Priabonian" beds of Diablerets with the middle Lutetian and with the Pilatus beds below the Flysch. In a later paper (**10**) A. Heim replies to J. Boussac's arguments and brings forward further arguments for his original contention that the "Priabonian" is a facies of the Lutetian. It would be tedious to recapitulate the arguments used, moreover, a knowledge of the local geology of the Swiss Alps is essential. The question will doubtless be further discussed.

Application of A. Heim's views to Indian Geology.

If A. Heim's views prevail, it cannot be doubted that their effect will not be merely a modification of the interpretation of some sections of the Swiss Alps, but rather of our views as regards the sub-dividing of the Eocene and Oligocene by means of their included Nummulites. Their effect will be far-reaching and not without influence upon our interpretation of Indian Tertiary geology. If the upper Khirthars containing *N. complanatus*, etc., are succeeded by Naris containing *N. sublævigatus* (E. Vredenburg's *N. intermedius*, Verbeeck's *N. sub-Brogniarti*) and *N. vascus*, we have now to decide (1) how far we can define the precise age of those beds on the evidence of the foraminifera, and (2) whether the absence of a "Priabonian" fauna implies a palæontological gap or not. And if we follow A. Heim, I think we must conclude that the nummulites do not give us evidence of a palæontological break. The absence of the "Priabonian" will thus appear to be the absence of a particular facies. Certainly the view of A. Heim is attractive when applied to Indian geology. The Nari transgression in India would be reduced to the rank of local unconformities, and the difficulty of explaining the total absence (except for the doubtful section in the Mula Pass in Jalawan State, Baluchistan, which is referred to by E. Vredenburg, **5**, p. 90,) of any Priabonian deposits is explained. The absence of any visible unconformity between the Khirthars and the Naris in Burma is also explained.

Dr. Heim's views are not altogether new.

A. Heim points out that his views on the distribution of Nummulites, although they may appear somewhat revolutionary, are in reality not new. As early as the year 1879, he tells us that Max von

Hantken (**11**) arrived at very similar conclusions in his work on the Tertiary of Hungary, and that he did not agree with the French geologists who place the *N. striatus* beds of the Gran country in Central Hungary above the beds containing *N. lucasanus, perforatus, complanatus*, and *A. spira.* He also expresses the opinion that the Ronca Beds near Verona are to be regarded as the same in age as the beds of San Giovanni Ilarione. E. Haug (**4**, p. 1488) doubtfully places the former in the Auversian and the latter in the Upper Lutetian.

M. von Hantken expresses the opinion that the beds in Hungary containing *N. Tchihatcheffi* are of the same age as those beds which contain *N. intermedius*; this proposition is less startling than it appears, since his work was published before *N. Fabianii* had been separated as a distinct species from *N. intermedius.* The Egyptian species identified by De La Harpe as *N. intermedius* D'Arch. (**29**) is really *N. Fabianii* as J. Boussac has pointed out (**30**) and the two species have frequently been confused. *N. Tchihatcheffi* is a megaspheric form corresponding to *N. complanatus* or *N. distans*, and should be regarded as Lutetian.

A. Heim also notes that De La Harpe (**12**) places the zone of *N. contortus-striatus* below the zone of *N. complanatus-Tchihatcheffi*, contrary to the scheme of the French geologists. It is very clear that the views expressed by J. Boussac in his table of the distribution of the Nummulites and Orbitoides (**13**) and repeated by E. Haug (**4**, p. 1421) are not universally accepted.

The views of Arnold Heim are however opposed to those of so many eminent geologists, including H. Douvillé, J. Boussac and P. Oppenheim, that very careful investigation is necessary before adopting them as an explanation of the absence of Bartonian fauna in India. J. Boussac's contention that the Einsiedlerschichten or Flysch contain at their base beds of Lutetian. Auversian or Priabonian ages at different points, is based upon the very reasonable hypothesis that the marine transgression of the Flysch over the underlying formations was a gradual one, lasting through more than one geological stage, and dependent upon the gradual encroachment of the sea.

This hypothesis, while reasonably commending itself to Alpine geologists, must however, if applied to India, again raise difficulties

of another sort. The gap between the Naris and Khirthars according to E. Vredenburg (**5**, p. 89) "corresponds chiefly with the Bartonian, typical representatives of which are not known in India." But if we accept J. Boussac's theory, are we not at once confronted with the need for an explanation of the horizontality of the Nari-Khirthar unconformity over an area so much larger than that dealt with by Arnold Heim and J. Boussac? As in the case of the Alpine Flysch, should we not expect the base of the Naris to vary considerably in age?

From the foregoing remarks, it now appears that the greatest caution must be exercised in dealing with the evidence of nummulites alone. In the present state of our knowledge of the distribution of the Assilines, it would be unwise to attempt to distinguish an upper from a lower Lutetian horizon in Burma from the occurrence of either *A. granulosa* or *A. spira*. The value of the zone nummulites of the Bartonian-Ludian stages has been challenged by Arnold Heim, who claims that this fauna may be of Lutetian age. With regard to such forms as *N. sub-lævigatus*, which has hitherto been regarded as a zone fossil of the Oligocene, the greatest care must be exercised. It has been shown within the last decade that there is an ancestor of *N. intermedius*, namely *N. Fabianii*, which is believed to characterise the Bartonian-Ludian stages. Before we permit ourselves to draw deductions from the occurrence of *N. sub-lævigatus*, we must be quite certain that amongst its many varieties, not merely some, but *all* approach more closely to the type of *N. intermedius* than to that of *N. Fabianii*.

Conclusion.

If now we turn to a consideration of the value of the Orbitoides as zone-fossils, we find that we are treading upon the same uncertain ground as was the case when we were reviewing the Nummulites. It may not be out of place here to recapitulate briefly the more recent views upon the distribution of the Orbitoides, and of their two sub-genera the Orthophragmina and the Lepidocyclines. In French perhaps the most well-known works are the monograph of MM. P. Lemoine and R. Douvillé on the genus *Lepidocyclina* (**14**) and the work of C. Schlumberger on the *Orthophragmina*, published in the Bulletin of the Geological Society of France. J. Boussac (**13**) in his table of distribution of the Tertiary foraminifera, includes the Orbitoides.

The Orbitoides.

I give below extracts from the table of Lemoine and Douvillé (**14** p. 31) and from that of J. Boussac (**13**).

P. Lemoine and R. Douvillé, 1904.

Burdigalian	Zone à *Miogypsina* seules.
	Zono à *Miogypsina* et petites *Lepidocyclina.*
Aquitanian	Zone à petites *Lepidocyclina* et *L. marginata.*
	Zono à *L. dilatata* et
	Zone à *L. mantelli.*
Stampian	

AFTER J. BOUSSAC, B.S.G.F., 1906, p. 558.

Rupelian (Stampian)	*N. intermedius, vascus, Bouillei.* Premières Lepidocyclina.
Lattorfian	*N. intermedius, vascus, Bouillei* ni *Lepidocyclina* ni *Orthophragmina.*
Ludian	*N intermedius, vascus, Bouillei.* Dernières Orthophragmina
Bartonian	*N. striatus, N. cf. vascus, Fabianii. Orthophragmina* nombreuses. Apparition do *Spiroclypeus.*

NOTE :—There is no mention of Orthophragmina in this table in the Auversian and Lutetian periods. G. deP. C.

These two tables taken together give a fairly clear idea of the views held in France on the distribution of the *Orbitoides.* I must add that in E. Haug's text-book (**4**) is shown between the Rupelian and the Aquitanian a stage named Chattian, which is characterised by the simultaneous occurrence of nummulites and lepidocyclines, and that the lepidocycline zones have since been somewhat modified by R. Douvillé.

Distribution of Orbitoides in India.

I now proceed to discuss the distribution of the *Orbitoides* in India. The reader will find the views of E. Vredenburg expressed in the table given above (p. 7) and in a subsequent paper (**15**). He says "The genera *Orthophragmina* and *Lepidocyclina* have never been met with together. *Lepidocyclina* characterises the Nari and Gaj, ... *Orthophragmina* occurs in great abundance throughout the Laki, the lower and Middle Khirthar and the lower zones of the upper Khirthar, those containing *Assilina spira* and *Nummulites perforatus*." He sums up with the conclusions that *Orthophragmina* and *Lepidocyclina* have never been found together; that the only large or medium nummulites found with *Lepidocyclina* are *N. intermedius* and *N. vascus*, that there is almost always a very wide stratigraphical gap between the Eocene and the Oligocene; that in almost every section *Orthophragmina* occurs up to the top of the Eocene and Lepidocyclina from the very base of the Oligocene so far as these series are developed.

With reference to the distribution of Lepidocyclines, he adds :—

> "There are no lepidocyclines answering to the description of either *L. Mantelli* or *L. Raulini*. All the lepidocyclines observed with *N. intermedius* and *vascus* belong to the group of *L. dilatata* with narrow pillars and a megasphere entirely surrounded by the second chamber. *L. dilatata* exclusively characterises the Nari both Lower and Upper. It is Carter's *Orbitolites Mantelli*. The Gaj contains no large nummulites and is characterised by lepidocyclines often of large dimensions, belonging exclusively to the group of *L. marginata* with large pillars and megasphere only partly enveloped by the second chamber."

The correspondence between the Indian zones and those of Lemoine and Douvillé is very striking. There are several points, however, which are not clear.

Difficulties against placing implicit reliance on the different zones of Orbitoides.

First, it is very doubtful whether the species assigned to *L. marginata* can really be identified with *L. marginata* Mich., since the former from the description appears to be a megaspheric form, and no megaspheric form of *L. marginata* was then known (**14**, p. 16).

Secondly, R. Douvillé (**19**) in discussing the disposition of central cells of the megaspheric forms says: "The difference of form is always very clear between the megaspheres of the Lepidocyclines of the type of *L. dilatata*, and those of the type of *L. morgani*. Only certain small forms coming from the East Indies appear to present a form intermediate between the two preceding types, although they appertain almost surely to the second by reason of their very small dimensions (2mm)."

Thirdly, it now appears that forms with large pillars may occur at a lower horizon than the Upper Aquitanian, while the range of the *L. dilatata* group must be extended upwards. For in a subsequent paper (**20**) R. Douvillé describes a form *L. præmarginata*, which is found together with *L. dilatata* and *N. intermedius* at Dego (Piedmont) and describes a new species *L. subdilatata* very closely allied to *L. dilatata* from beds which he assigns to the Upper Burdigalian.

Several Italian geologists hold somewhat different views regarding the distribution of *Orbitoides* from those of the French.

The Italian view.

F. Sacco (**16**) tells us that *Orthophragmina* occurs in the Tongrian of Colli Berici in beds containing *N. intermedius-Fichteli*, and proceeds to quote several instances of the occurrence of *Lepidocyclina* in the Eocene. More recently G. Checchia-Rispoli (**17**) has written a monograph upon the Tertiary of Palermo in Sicily, in which he describes the occurrence of *Orthophragmina* and *Lepidocyclina* in the same beds, and concludes that the sub-genus *Lepidocyclina* makes its appearance in the Lutetian. His conclusions are very much at variance with those of Henri and Robert Douvillé; the latter of these two authorities (**31**) had previously offered a possible explanation on structural and other grounds (see **4**, p. 1483) and regards these Palermo beds as a mixture of Lutetian, Tongrian, and Aquitanian deposits.

The latest contribution of the Italian school on this subject comes from the pen of Dr. P. L. Prever (**18**) published in 1912. He notes the absence of *Lepidocyclina* (*vide* pp. 19-21) from the Eocene of Northern Italy, while not denying the possibility of its presence in the Sicilian Eocene as stated by Di Stephano and Checchia-Rispoli.

It may not be out of place here to quote the opinion of E. Haug which is given in the last part of his text-book (**4**, p. 1420)

which was published in the year 1911, and represents the up-to-date opinion of one of the most eminent of French geologists. He says :—" We know that the genus *Orbitoides* (*sensu stricto*) does not survive at the end of the Cretaceous period, and that it is replaced from the Montian by the genus *Orthophragmina.* This attains its maximum in the upper Lutetian, where it is represented by numerous species. The last are found in the Ludian. No Orbitoides is known from the Latdorfian ; but in the Rupelian one observes the appearance of the genus *Lepidocyclina,* which continues up to the lower division on the Neogene, where it is associated with *Miogypsina.* If the Nummulites permit the definition of zones and stages, the Orbitoides furnish characters valuable for the delimitations of great divisions."

Conclusion

The correspondence between Indian and European Orbitoides zones is no longer so harmonious as it appeared a few years ago, when the student had only Lemoine and Douvillé's monograph and E. Vredenburg's paper to refer to. R. Douvillé's subsequent work shows that forms akin to *L. dilatata* may occur* in the Upper Burdigalian, and forms akin to *L. marginata* in the Stampian. There is doubt as to the identity of the Indian species of *L. marginata,* and R. Douvillé's interesting observations on the megasphere of East Indian lepidocyclines show that we should be cautious in assigning an age from the disposition of the central cells alone. It is but just to remark that R. Douvillé's specimens from the " East Indies " were not from India, but from Java and Madoura.

II. The relationship of *Nummulites scaber* and *N. aturicus* to other species, and the modes of Classification of Nummulites.

Before proceeding to a description of the nummulites of the Yaw stage, it will be necessary to preface our enquiry by a few remarks on the two species *N. scaber* and *N. aturicus.* In D'Archiac's monograph, the latter species appears as a variety (*aturensis*) of *N. perforatus.*

De La Harpe (22) includes a large number of species in t e varieties of the species *N. perforatus.* He says (22) " Just as *N. gizehensis, Lyelli, Caillaudi,* and *Zitteli* are one single and identical species divisible into races and varieties, so *N. perforatus, Sismondai, Verneuili, Lorioli, Renvieri,* and *Bellardi* should be reunited in one

species, with numerous races and varieties, due for the most part to local influences which have modified certain characters in a particular fashion."

De La Harpe (**21**) mentions another variety of *N. perforatus*, namely, var. *uranensis*, of which more will be said.

In French publications, the name *N. aturicus* appears to be frequently used instead of *N. perforatus*, thus we find this species alluded to in a paper of J. Boussac (**9**) as *N. aturicus* var. *uranensis*.

H. Douvillé (**32**) makes some interesting remarks upon the "denomination of nummulites" and upon the correct name of this species in particular; these remarks I will not quote, but the reader may refer to them if he wishes.

H. Douvillé in another paper (**22**) regards *N. aturicus* as a relation of *N. lævigatus*, and says :—

> "The reticulated and granulated nummulites constitute a second branch which characterises by its appearance the Lower Lutetian. Professor Haug has noted in *N. contortus* tiny indentations along the septal filaments, analogous to those we have shown in our figures of *N. lævigatus*; we have found them also upon all forms of the same group, *N. planulatus*, *N. atacicus*, *N. biarritzensis*. It is the development of this character which gives rise to the group of reticulates; the indentations, increasing in importance, become actual ramifications, while at the same time they swell in places, and thus produce characteristic granulations. These ramifications react generally upon the septal filaments, which become much more irregular and sometimes show sudden bends or retroflexures at the points where certain of these ramifications break off. Thus arise the forms *N. lævigatus*, granulated only in youth, then *N. scaber*, which is strongly granulated in the adult. This last form at least persists through the middle Lutetian, while there arise two very characteristic derived species; one is remarkable for its great thickness and its very rounded form, that is *N. crassus* (*N. perforatus* auctores) which is strongly granulate in youth, but generally becomes almost smooth in the adult age. The second is distinguished by a much more rapid increase in size, the granulations are very slightly developed and only in youth, but in compensation the

species attains a very large size, up to 10 cm. in diameter; this is *N. complanatus*, which remains always characterised by the marked irregularity of its filaments. Another modification brings about the reduction of the size of the granules............this is *N. Brogniarti.* .... *N. crassus* is replaced in the upper Lutetian by a form less thick, in which the granules persist in the adult state, between the filaments, and always very clearly marked; this is *N. aturicus.* In all this group variations occur in such a way that species (mutations), are not always easily distinguished from varieties."

In another and previous paper H. Douvillé makes the following interesting remark (**27**, p. 209):—

"These ramifications themselves present irregular swellings, which as they develop produce granules or tubercles; it follows therefore that the granulated or tuberculated forms are merely in reality a particular case of the reticulated. That is an arrangement which appears general, and which we believe exists equally upon *N. aturicus* (*perforatus* auct.) contrary to what De La Harpe thought. It follows that it is no longer possible to distinguish three principal groups of nummulites, radiate, tuberculate, and reticulate, but only two, radiate and reticulate, these last being often tuberculate at least in youth."

Phylogeny of N. aturicus after H. Douvillé.

I give below a table showing the phylogeny of the *N. aturicus N. scaber* group after H. Douvillé, and taken from his table of the Phylogeny of the Nummulites (**23**, p. 41).

Reticulate Nummulites.

Stampian				
Sannoisian.			intermedius-Fichteli.	
Wemmelian.				
Auversian			cf intermedius.	
Lutetian	Upper		aturicus	
	Middle	Brogniarti Deshayesi.	crassus-Lucasi.	complanatus gizehensis.
	Lower		scaber, laevigatus-Lamarcki	

This is only a portion of H. Douvillé's table.

Names of species of Nummulites.

Before I pass on to a further consideration of this subject I wish to note that the student of Nummulites has in the present day great difficulties to face in choosing the name of his species. We have seen that the familiar name *N. perforatus* has now been practically discarded, and we find the names *N. aturicus, N. crassus* used in its place. No doubt it is desirable to use the name under which the species was first described, but it seems a pity that a familiar name used so often by D'Archiac and De La Harpe should have been discarded in favour of unfamiliar names, although older, in view of the amount of confusion likely to arise. However, *N. aturicus* is, as defined by H. Douvillé, distinct from *N. crassus* and both would be included in D'Archiac's *N. perforatus*, so that in this case there is ample justification.

I think it is also a matter for regret that many authorities still use different specific names to indicate the megaspheric and microspheric forms of the same species. An example of a case from which confusion might easily arise is to be found in the *Paleontologia Universalis* plates 115 and 116, where we find that the same species is described under two different generic names. This species is *Nummulites contortus-striatus*.

The megaspheric form is called *Camerina striata* Bruguiere 1792, while the microspheric form is called *Nummulites contortus* Deshayes 1834. The writer (J. Boussac) in his remarks on *Camerina striata* certainly warns us against the adoption of the name *Camerina* as a substitute for *Nummulites*, but even then, the large heavy type label "*Camerina striata*" at the top of the page appears to me to be calculated to confuse those who are not thoroughly familiar with the species. Not less confusing is the suggestion on Plate 116 under the heading *Nummulites contortus*, that this form should be called *N. striatus* ("En vertu des lois de la priorité *N. contortus* devrait donc porter le nom de *N. striatus*"). M. Boussac can hardly be blamed for a confusion which existed long before the appearance of these plates. Yet the case is worth quoting, if only to emphasise the desirability of standardising our nomenclature of the Nummulites.

A similar cloud of obscurity appears to hover over the relationships of *N. atacicus* and *N. biarritzensis*, as in the case of *N. perforatus*, *N. crassus*, and *N. aturicus*. This I need not discuss.

The Italian Mode of Classification.

D'Archiac, De La Harpe and most other authorities including, as we have seen, H. Douvillé recognise the excessive degree of variation amongst the nummulites. Italian palæontologists have on the other hand adopted a rigid system of classification, based upon external characters, which is set forth in the publications of A. Tellini (**24**, **25**) and of P. L. Prever. The latter (**26**) divides the genus *Nummulites* into the sub-genera *Bruguieria*, *Laharpeia*, *Gümbelia*, and *Hantkenia*. E. Haug (**4**, p. 1420 footnote) remarks that these names are scarcely ever used, and again (p. 1483) says :—" Furthermore the greater part of the new species described by this author " (Prever **26**) " are unrecognisable, being established solely upon median sections which do not furnish any serious specific character."

In a very recent publication Dr. Prever gives his latest classification (**18**, p. 242) which I sub-join :—

- Nummulites . .
  - Camarina . . .
    - Bruguieria (reticulate).
    - Laharpeia (reticulate granulate).
  - Lenticulina . . .
    - Gumbelia (striate-granulate).
    - Paronaea (striate).
  - Assilina.

The objection to this is obvious. Those forms described by H. Douvillé as showing granulation in youth, but in which granulation disappears in the adult will be attributed to different sub-genera. The whole tenour of H. Douvillé's remarks appears to me to form a decisive argument against thus splitting up the nummulites into sub-genera in this manner.

Of the species described by the Italian authors, *N. Fabianii*, *N. miocontortus* and *N. Rosai* appear to be generally recognised.

A. Heim's two species N. uroniensis and N. gallensis, and his mode of classification.

The memoir of A. Heim (**6**) which has been already alluded to contains a palæontological portion devoted to the nummulites. He divides the genus into three sections :—

(1) Leisten einfach ; Oberfläche nicht granuliert.

(2) Leisten einfach bis halb netzförmig ; Oberfläche (der inneren schalen) granuliert.

(3) Leisten netzförmig.

This seems to be a sound classification, provided the sections are not regarded as of sub-generic rank but rather, like D'Archiac's divisions, as convenient groups.

He describes two species *N. uroniensis*, which is De La Harpe's *N. perforatus* var. *uranensis* (see *ante*) and *N. gallensis* previously referred to as *N.* cf. *aturicus*. He includes the megaspheric and microspheric forms under one specific name; this method appears very simple and attractive.

My Burmese specimens somewhat resemble A. Heim's species.

Dr. Prever on A. Heim's species.

A. Heim's two species *N. uroniensis* and *N. gallensis* are regarded by Dr. Prever as a mixture of several species (**18**). He identifies *N. gallensis* with various species belonging to his sub-genera *Laharpeia*, *Gümbelia*, and *Paronaea*. Certain of the specimens figured by A. Heim which show a greater degree of reticulation and granulation than the rest are identified with the species *Laharpeia tuberculata* Bruguiere, which he regards as the same as D'Archiac's *N. scaber*.

Difficulty of separating *N. aturicus* from *N. scaber*.

The difficulty of separating young specimens of *N. aturicus* from those of *N. scaber* has been commented upon by H. Douvillé (**27**, p. 210). He mentions the collections of M. Benoist in the nieghbourhood of Bordeaux, and says that the latter "considered the feebly granulated flat forms as a variety *aquitanica* of *N. lævigatus*; it is very certain that the word race would have been more strict. With this form B. is associated a form A. considered likewise as a variety or race of *N. lamarcki*. Nevertheless together with these forms there exists another more granulated and more swollen, which M. Benoist considers to be *N. aturicus* (*perforatus* auct.); but it follows from the observations which we have made, that it is only the tuberculated variety of the preceding species. The forms collected from the Bordeaux borings rarely present the normal form of the adult; and if at least up to the present it appears difficult to separate young forms of *N. lævigatus* var. *tuberculata* from young forms of *N. aturicus*, these two species or mutations none the less appear to correspond to somewhat different horizons and take part in distinct faunas."

When examining the specimens of nummulites from Burma, I have been much puzzled by a similar difficulty, that is whether

they should be referred to *N. scaber* or to *N. aturicus*. Like the Bordeaux specimens, these also appear to be dwarfed forms. The same difficulty appears to have arisen in the case of A. Heim's species *N. gallensis*, a portion of which Dr. Prever refers, as we have seen, to *N. scaber*. This point will be further discussed.

III. The Burmese Nummulites.

The specimens from Burma about to be described were collected from the following localities :—

A. 1 mile south-east of Tazu village, (21° 17′ 30″; 94° 19′ 40″).

B. From a limestone reef in shale ¼ mile west of Kyauktaga village, (21° 27′; 94° 19′ 15″).

C. Very close to the spot where the cart-track from Kyaukleik village to Man village crosses the Thanpaya Chaung, (21° 19′ 55″; 94° 16′ 25″).

D. (Reg. No. K.-15 398) 3½ miles west-south-west of Yethama village, (20° 52′; 94° 24′.

The specimens from the first three localities were collected by myself, and those from the fourth by Sub-Assistant Sethu Rama Rao.

These nummulites all resemble each other so closely that I have no hesitation in ascribing them all to one species; nevertheless they exhibit differences which I regard as of varietal nature. There are two varieties, which I will call (1) and (2): var. (1) occurs at locality A., var. (2) occurs at localities, B, C, and D.

I have referred these specimens to the groups of *N. aturicus* and *N. scaber*. They do not correspond to specimens figured in the books to which I have referred. I, therefore, describe them under a new name.

Nummulites Yawensis n. sp.

Variety (1).

The first variety from locality A is figured on Pl. I, figs. 1-6 and Pl. II, figs. 1-9. The microspheric form is figured on Pl. I, figs. 1-6. The megaspheric form is figured on Pl. II, figs. 1-9; while the equatorial section of the megaspheric form is shown in Pl. II, figs. 10-12. The specimens shown in the figs. 10-12 are from locality B, where the preservation is much better than in locality A, and permits of their being ground down.

Microspheric form of var. (1).—The dimensions in milimetres of ten specimens are :—

Diameter.	Thickness.
9½	2½
8	3
9	2½
9½	3
6	2
9	2½
7½	2½
8	2½
6½	2½
6	2

The surface ornamentation consists of radiating striæ occasionally anastomosing, but not reticulate; there is a loose mesh structure in the central region, very similar to that shown in the figures of *Nummulites contortus* (*vide Palæontologia Universalis*; figs. 115 and 116). Trabeculæ are not visible upon the striæ, but the specimens are usually sparsely granulated, the granulations either breaking up the striæ into radiating rows of granules or occurring between two striæ. Granulation is less developed upon this variety than upon the other variety, but may be seen in Pl. I, fig. 5. The sparse development of granulations is probably connected with the flat habit of this variety as distinguished from the more swollen habit of the other form. Another interesting point is that the flatter the specimen, the more wavy the striæ appear to be. Pl. I, Fig. 4, may be compared with fig. 5 in this respect. A few of the flatter specimens show on parts of the surface a very loose mesh structure, but this is rare, and appears to be only a local irregularity, since the same specimen shows typical radial striæ over the greater part of its surface. The markings of the decorticated surface are exactly similar to those of the outside, except that granulation is not seen.

Many of the specimens are mammillated. The edge is fairly sharp.

The ornamentation in this and in the remaining varieties may be compared to that shown on A. Heim's figures of *N. uroniensis* and *N. gallensis*, which are both closely related to *N. aturicus*.

The equatorial section is shown on Pl. I, figs. 1, 2. There is a very striking likeness between the equatorial section and that of *N. contortus* (*Pal. Univ.*, fig. 116). A similar resemblance has been

noted by A. Heim in the case of his species *N. uroniensis* (**6**, p. 228). There are about 13 whorls in a radius of 4 mm. and 8 whorls in a radius of 2 mm. The number of septa is as follows :—

No. of whorls from Centre	No of septa in one Quadrant
13	17
12	15
11	12—14
10	12—14
9	12
8	9—10
7	8
5	7
3	5—6

The height of each cell varies from twice to one and a half times the breadth. The posterior superior angle is variable between 45° and 60°. The anterior inferior angle tends to approach 90° and sometimes exceeds this, when the septa are curved forwards (see figures). The spiral lamella is thin, about one-fifth the height of the cells. The septa occasionally anastomose. The resemblance of the equatorial section to that of *N. contortus* has been noted. As compared with A. Heim's two species, it may be noted that the septa are rather more closely packed, the cells higher and narrower, and the spiral lamella thinner. The equatorial section also reminds us of Verbeeck's figure of *N. laevigatus* (**3**, Pl. VIII, fig. 104). The ornamentation is, however, quite distinct from Verbeeck's specimens of *N. laevigatus-Jogjacartae* or from that of those from Borneo figured by Messrs. Newton and Holland (**28**).

An important difference between these species and the typical *N. perforatus* (*aturicus*) lies in the disposition of the external whorls as seen in the equatorial section, which are not pressed close together as in *N. aturicus*, but resemble much more closely the *N. laevigatus-scaber* forms in that each whorl is larger than the preceding one. The rarity of reticulation, however, does not permit of their being referred to this species ; very possibly they represent an intermediate type between the two species *N. aturicus* and *N. scaber*. It is a difficult question to decide to which group they belong.

The Megaspheric Form. I am unable to detect any difference between the megaspheric forms from the various localities mentioned. It will be sufficient, therefore, to describe only the microspheric form

of the other variety. Of the megaspheric forms figured, those showing external markings come from A and those showing the equatorial section come from B.

The dimensions in millimetres are as follows :—

Diameter.	Thickness.
$3\frac{1}{4}$	1
$2\frac{3}{4}$	1
$2\frac{1}{4}$	1
3	$1\frac{1}{4}$
$4\frac{3}{4}$	?

The surface is ornamented with radiating granulated striæ, the marking being very similar on a miniature scale to that of the microspheric form. The granulations are, however, more developed. There are 7-8 whorls. There is a large central chamber, the diameter of which is about ·08 mm followed by a semi-lunar second chamber. There are 10 septa in a quadrant of the 7th whorl; 9-10 in a quadrant of the 6th; 7-8 in a quadrant of the 5th, 6-7 for the 4th, 5-6 for the 3rd. The total number of cells is between 150 and 200.

The general shape of the cells is similar to that of the microspheric form. The specimen shown on Pl. II, fig. 10, differs somewhat from the rest in showing a tendency towards reticulation in the frequent anastomosation of the radiating striæ, and the occasional junction of two striæ, forming on parts of the surface a loose mesh. It may be regarded as the megaspheric form of variety (2). It is closer to the type of *N. joguiacartæ* than the other figured specimens; it is also the largest of the megaspheric forms (diam. $4\frac{3}{4}$mm.).

Variety (2) microspheric form.

The diameter is 5-6 mm, and the thickness averages $2\frac{1}{2}$ mm. The surface ornamentation is shown on Pl. III, figs. 4, 6-9, The radiating striæ are granulated, but more often granulation is noticeable upon the very fine "trabeculæ" which run from one ray obliquely to the neighbouring one, and form a loose mesh. These trabeculæ which are of the same kind as those discovered by Professor Haug upon *N. contortus* are very much finer than the main radiating striæ.

This variety approaches somewhat to the group of *N. scaber*. With it may be joined the megaspheric form, the equatorial

section of which is shown on Pl. II, fig. 10. Both these specimens show a greater tendency towards reticulation than the normal. Other specimens from the same locality which I have referred to this variety show trabeculæ stopping short before they reach the adjoining ray. In these the trabeculæ project at right angles from the ray and are not set obliquely.

Equatorial sections are shown on Pl. III, figs. 1, 2, 3, 5, 10, 11,

There are about 11 whorls, rather irregular and increasing in size steadily. The following is the number of septa per quadrant :—10th whorl—15; 9th—13; 8th—10-11; 7th—7-8; 6th—6-8; 5th—6-7; 4th—6.

In the inner whorls the septa are almost straight. On the average, the posterior superior angle is about 60°, but the septum bends round rapidly to the perpendicular.

Relationships of N. yawensis. The difficulty of distinguishing undeveloped specimens of *N. aturicus* from *N. scaber* has been already noted. Var. (1), the flatter and larger variety, approaches in ornamentation more nearly to *N. äturicus*. Var. (2) shows occasional elongated meshes, formed by striæ united by fine trabeculæ, and by the anastomosation of the striæ themselves. It is closer to *N. scaber* than var. (1). Both varieties are smaller than the two types to which I have compared them, *N. scaber* and *N. aturicus*. We are perhaps justified in regarding them as annectant types between the two species.

Age of N. yawensis. Var. (2) occurs at locality D in company with small megaspheric papyraceous *Orthophragmina*. These last measure 7 to 8 mm. by 1¼mm. in thickness, and are megaspheric, the second cell being very much larger than the first. They correspond exactly with I. Provale's figures of *O. sella* D'Arch (**34,** p. 74 and Pl. V, fig. 13). They are, therefore, to be referred to this species. The molluscan fauna, which will be described in another paper, accompanying the nummulites appears more closely related to the Upper Eocene than to the Oligocene.

I, therefore, believe them to be of upper Eocene age.

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EXPLANATION OF PLATES.

PLATE I

NUMMULITES YAWENSIS n. sp.

FIG. 1.—Microspheric form, var. 1, from locality A; equatorial section approx. mag. 7 times.

FIG. 2.—The same; another specimen from locality A, approx. mag. 7 times.

FIGS. 3, 4, 5, 6,—The same; other specimens from locality A, showing external ornamentation; approx. mag. 7 times.

PLATE II.

NUMMULITES YAWENSIS n. sp.

FIGS. 1—9. Megaspheric forms, from locality A, showing external characters; approx. mag. 9 times.

FIGS. 10-12.—Megaspheric forms, from locality B, equatorial sections, approx. mag. 6¾ times.

PLATE III.

NUMMULITES YAWENSIS n. sp.

FIGS. 1, 2, 3.—Microspheric form var. 2, from locality B, equatorial section, approx mag. 6¾ times.

FIG. 4.—Microspheric form, var. 2, from locality B, showing external ornamentation, approx. mag. 6¾ times.

FIG. 5.—Microspheric form, var. 2, from locality C, equatorial section, approx. mag. 6¾ times.

FIG. 6-9.—Microspheric forms, var. 2, from locality C, approx. mag. 6¾ times.

FIGS. 10-11.—Microspheric forms, var. 2, from locality D, equatorial sections, approx. mag. 6¾ times.

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CONTRIBUTIONS TO THE GEOLOGY OF THE PROVINCE OF YÜNNAN IN WESTERN CHINA. IV. THE COUNTRY AROUND YÜNNAN FU. BY J. COGGIN BROWN, M.Sc., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plate 4.)

INTRODUCTION.

THE area to be dealt with in this paper lies around Yünnan Fu, the capital of the province of Yünnan, and is comprised within Sheets 31 N.E. and S.E. of the North-East frontier surveys. It forms the north-western part of the great lakes' region of eastern Yünnan, and owing to its proximity to the railway which now connects the Chinese province with Tongking, certain portions of it have been surveyed in detail by various French geologists.

Previous work.

E Joubert.

E. Joubert, who accompanied the expeditions which explored Indo-China during the years 1866-1868, under the leadership of Doudart de Lagree and Francis Garnier, appears to have been the first geologist to visit the Yünnan Fu district. On the map which he compiled and which was completed by H. E. Sauvage, the area is entirely occupied by beds of Devonian and Triassic age.[1]

E. von Loczy.

On the map which accompanies E. von Loczy's account of his travels with the Szechenyi expedition in 1877-1880, Joubert's results appear to have

[1] Voyage d'exploration en Indo-Chine, Paris 1873, Vol. II, p. 170.

been taken for granted, as Loczy himself did not visit the regions in question.[1]

P. A. Duclos.

In the report of the Lyons Mission, the members of which travelled extensively in China during the years 1895-1897, P. A. Duclos has given a summary of the Chinese mineral industry, in the provinces of Yünnan, Kwei-chou and Ssu-ch'uan. A few notes on the geology of the mining centres of Yünnan are added. Attention is directed to the occurrence of crystalline rocks on the Yünnan-Tongking frontier, to the wide-spread covering of Devonian or Carboniferous limestone found over eastern Yünnan, to the presence of hard red sandstones in the north-east near the Yangtze Chiang, to which a Permian or Triassic age is tentatively given and to the association of eruptive volcanic rocks with them. Anticipating later results, Duclos regarded the folding which has produced the mountain ranges of Yünnan as contemporaneous with that of the Himalaya. He was also impressed by the very vigorous action of the ordinary processes of denudation, aided by the strong prevailing winds and the deforestation which has been universally carried on.[2]

M. A. Leclere.

During the years 1897-1899, M. A. Leclère travelled extensively in the Chinese provinces of Yünnan and Kwei-chou. According to him, the limestones which attain so remarkable a development in the districts he visited, belong to the most diverse horizons ranging from the Devonian to the Lias. Leclère laid the foundations for the study of the systematic geology of eastern Yünnan, determined the age of the limestones around Yünnan Fu as Permo-Carboniferous, directed attention to the salt-bearing upper Permian which overlies them, and recognised the thick series of upper Carboniferous eruptive rocks. On the small geological map added to his report, the whole of our area is shown in two colours; one of these represents the Devonian, Carboniferous and lower Permian, and the other the upper Permian and Trias.[3]

[1] Die Wissenschaftlichen Ergebnisse der Reise des Grafen Béla Széchenyi in Ost Asien 1877-1880, Vol. I, map.

[2] La Mission Lyonnaise d'exploration commerciale en Chine 1895-1897. Lyon 1898, pp. 283—314.

[3] Étude géologique et minière des Provinces Chinoises voisines du Tonkin. *Annales des Mines*, Vol. XX, 9me Ser. pp. 287—492.

G. H. Monod.

G. H. Monod in 1898 accompanied Leclère for some time and has published a communication containing his views on the geology of the areas he visited. Though in agreement for the greater part, these are not accepted entirely by Leclère.[1]

H. Lantenois.

Further surveys were carried out in the regions bordering on two proposed railway lines from the Tongking frontier to Yünnan Fu by H. Lantenois in 1903-1904. The fossil collections were determined in Paris by H. Mansuy, under the direction of Professor H. Douvillé. Lantenois found fossiliferous strata belonging to the lower Cambrian and upper Carboniferous as well as lacustrine deposits of late Tertiary age which fill up large numbers of lake basins in Yünnan.[2]

Date of present traverses.

My own work in the area around Yünnan Fu was done during February-April 1908 when I arrived there from Ta-li Fu on the west, and again, in May 1909, when I approached it from Hui-li Chou in Ssu-ch'uan on the north-west, after a journey down the Yangtze Chiang valley.

J. Deprat and H. Mansuy.

During the years 1909-1910 and part of 1911, eastern Yünnan has been geologically surveyed by J. Deprat and H. Mansuy of the Service géologique de l'Indo-Chine. Their joint results have recently been published in a series of voluminous memoirs.[3]

My own work was therefore completed before the detailed French survey was commenced, but the publication of my results has been delayed until the present opportunity, chiefly by continued work in the field. Though I am not in perfect agreement on all points with Deprat and Mansuy, I gladly admit that their researches on the lines originally laid down by their colleagues and fellow countrymen, have carried our knowledge of the geological history and structure of this complicated region very much further than I could have done myself, owing to the conditions under which I was compelled to work. I was very hampered

[1] Contribution à l'étude géologique des Provinces méridionales de la Chine. Saigon 1902.

[2] Résultats de la Mission géologique et minière du Yünnan méridional. *Annales des Mines* 10 me Ser., Vol. XI., pp. 298-503.

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by want of complete maps and by having to traverse great distances in the shortest possible time. As I have had opportunities of working in central and western Yünnan, I naturally regard the eastern portions of the province from that point of view, and therefore I hope that my contribution to the geology of eastern Yünnan may not be without its value, and will go to form a useful link in the chain of surveyed tracts, which now connects the field of operations of the Service Géologique de l'Indo-Chine with that of the Geological Survey of India.

Physical Geography.

General direction and elevation of mountain ranges.

Yünnan Fu lies at an elevation of 6,400 feet above the level of the sea, near the northern extremity of the plain which borders lake K'un-yang on the north and east. The plain is bounded on all sides by higher land crossed by ranges trending north and south or north-east, south-west and joined by shorter spurs running in different directions between them. More open plateau-like areas are sometimes found. The routes which approach the provincial capital from the west, north-west, north-east and east, wind across the tops of the ridges, attaining maximum elevations of about 7,500 feet and dropping again into the valleys at 5,500 to 6,300 feet approximately. The lowest valley plain is that of I-liang Hsien at 5,300 feet which is an exceptional altitude for this part of Yünnan. The cliffs bordering lake K'un-yang on the west rise up to 8,400 feet above the sea, but further north, close to the Yangtze Chiang, heights of 10,000 feet have been recorded.

The river systems.

The area lies in three great drainage systems; the overflow from lake K'un-yang reaches the Yangtze Chiang, and that from lake Yang-tsung, the Chu-tsing Ho which eventually becomes the Hung-shui Chiang flowing east and forming the boundary between the provinces of Kwei-chou and Kwang-hsi. The stream draining the Lu-fung Hsien valley reaches the Yuan Chiang or Red River of Tongking. The drainage from the Yang-lin neighbourhood enters the Niu-lan Chiang, a northerly flowing tributary of the Yangtze Chiang.

Great depth of some of the river valleys

As a direct result of the recent wide-spread elevatory movements which have affected eastern Yünnan and which I have discussed in a later paragraph, the valleys of the Yangtze Chiang and

some of its tributaries have been excavated to great depths. At Hung-men-kou, a ferry on this river north of Yünnan Fu, the elevation is only 2,800 feet, while the hills on each side rise to 11,000. According to Major Davies they "are extremely steep and a mass of rocks and stones, with a few little ledges where there is just room for a small village and a little cultivation."[1] Streams like the P'u-tu Ho, which drains lake K'un-yang have therefore excavated extremely deep and narrow cañons in order to reach the parent stream.

Trend of the better defined ranges.

Amongst the better defined ranges may be mentioned those which have their origin north of the Yangtze Chiang and are prolonged across the river towards Yuan-mou Hsien, Wu-ting Chou and Lu-chuan Hsien; an extension of one of these forms the high ridge bordering the Lu-fung Hsien plain on the west. Another range commences in the high country to the north-east of Yünnan Fu and is continued in the same direction towards Sung-ming Chou. The valley of the Pei-ta or Chu-tsing Ho near I-liang Hsien is defined by a high north and south running ridge. To the west of Yünnan Fu, smaller ridges are separated by a network of streams belonging to the Yangtze Chiang and Red River systems.

The stream which drains lake K'un-yang breaks through the high limestone wall on the west, and flows north-west to An-ning Chou in a narrow valley bounded by cliffs. At this place the valley becomes broader as it is in the soft rocks of the upper Permian, but it becomes constricted again as it turns north and north-east to the Yangtze Chiang.

Lakes K'un yang and Yang-tsung.

Lake K'un-yang is now approximately 24 miles long and 7 miles broad, but during comparatively recent times its waters have been captured by the P'u-tu Ho with a consequent lowering of their level. The great plain which surrounds Yünnan Fu and the towns of Chen-kung Hsien and Chin-ning Chou on the east is the former lake bottom, now intensely cultivated and covered with rice fields, gardens and orchards. There are other smaller plains formed in the same way; they are always chosen as the sites of the towns and contain by far the greater part of the population. Lake Yang-tsung is much smaller than K'un-yang, but is said to be very deep; like the latter it has been captured and

[1] Davies. Yünnan, the link between India and the Yangtze, p. 212.

diminished by a tributary of the Pei-ta Ho. It is surrounded by denuded and almost uninhabited mountains, though several important villages are situated at its northern extremity. The magnificent scenery around this lake is the admiration of all travellers who have been fortunate enough to see it; the effects are due as much to the shape and position of the lake as to the girdles of mountains which encircle it.

Character of the scenery derived from the Carboniferous and upper Permian rocks.

The upper Permian Red Beds series gives rise to deeply dissected country, often traversed by innumerable small valleys, dry during the winter, but each filled with its swiftly flowing torrent in the rainy season. The soils formed from these rocks are very ferruginous and poor and as a consequence little cultivation is done on them. As a rule they are bare or rarely covered with thin scrub jungle varied occasionally by pine forest.

The limestone areas form karstic country, dry and almost waterless, with pot holes and underground streams.

The Tertiary lake basins.

The Tertiary lake basins are small flat areas on which four-fifths of the population is concentrated. Instead of the bleak wastes formed by the other rocks, cultivation is carried on to an extraordinary degree, and fields of rice, barley, leguminous plants, maize and sugar cane alternate with orchards, vegetable and flower gardens, while the villages and temples of the Chinese farmers flank the lower slopes of the hills, so that none of the available cultivable land may be wasted.

Outlines of the Geology of Eastern Yunnan.

To understand the part which the present research plays in the elucidation of the geological history of eastern Yünnan, it is advisable to summarise briefly the more important results of previous workers, in the strip of country which runs southward from the Yangtze Chiang through Yünnan Fu to the borders of Indo-China. The area is comprised approximately within Longs. 102° and 104° and Lats. 23° and 26°. This summary is mainly based on Deprat's conclusions drawn from his own surveys, and those of his earlier colleagues modified by my own observations where they overlap theirs in the east, and where they are distinct from them in the central and western parts of the province.

Crystalline Rocks.

Crystalline rocks are not widely developed in eastern Yünnan. In the deep valley of the Red River, and on the borders of the Mong-tzu basin, mica schists accompanied by cipolins and amphibolites occur. Masses of leptynite and tourmaline bearing pegmatite are associated with them.[1] In the Ko-chiu neighbourhood these rocks contain cassiterite and the well-known tin deposits are the product of their disintegration. According to Lantenois the age of the granites must be between the Devonian and the Rhaetic [2], but Deprat who has also studied the granites of Tongking and Annam, regards the metamorphic series of the Red River, the lower Nam-ti valley and the Mong-tzu basin, as a profoundly altered Palæozoic succession ranging from the Cambrian to the middle Carboniferous; the granitic eruptions probably following the middle Carboniferous period of folding.[3]

Cambrian.

Rocks of this age were first recognised by Lantenois, and Deprat has shown recently that they attain a thickness of not less than 2,000 metres between the parallels of Yünnan Fu and the Yangtze Chiang. The series is essentially an arenaceous one, and varigated sandstones associated with slates and schistose shales are of far more frequent occurrence than the rare bands of brecciated and crystalline limestone. The rocks have been very disturbed by tectonic movements, but as a rule two divisions can be recognised, in spite of the local variations inseparable from the formation of detrital deposits in shallow seas.

Deprat groups these two divisions as follows:—

Argillo-arenaceous stage.	Beds with *Ptychoparia.*	Lowest Acadian.
	Beds with *Redlichia.*	Georgian.
Compact sandstone stage with *Redlichia* and intercalated limestones.		

Ordovician.

In a few places, small exposures of beds which come above the Cambrian have been shown by Deprat to belong to the Ordovician, but as the bands appear to have been very generally metamorphosed by earth

[1] They have been described by Michel Levy and Lacroix. *C. R. Ac. Sc.*, 29th January 1900.

[2] *op. cit.*, p. 72.

[3] J. Deprat. Sur les formations eruptives et metamorphiques du Tonkin. *C. R. Ac. Sc.*, 15th November 1909.

movements, the details of the succession have not been completely worked out as yet. The fossils which have been collected do not bear any resemblance to those which I obtained from the Pu-piao and Shih-tien beds of western Yünnan and which are at present under description by Mr. Cowper Reed[1]. Deprat has attempted to correlate the Ordovician beds of eastern Yünnan with those of the Shan States and of Spiti, but it appears to me safer to wait until better collections have been made in the former country before making deductions of this kind.

Silurian.

Deprat has recognised a Silurian horizon to the north of Yünnan Fu, and in the valley of the Nam-ti near the Tongking frontier, shales with *Spirifer Tonkinensis* appear to form a passage between the Gothlandian and the lower Devonian. It is difficult to correlate either of these horizons with the Silurian graptolite shales discovered by myself near Shih-tien in western Yünnan.

Devonian.

Since Richthofen described the middle and lower Devonian rocks of south-eastern China, our knowledge of these deposits in south-eastern Asia generally has been steadily growing, and they are now known to occur in many very widely separated localities. Eastern Yünnan is no exception to this rule and the presence of richly fossiliferous horizons has been known therein for a number of years.

I have already shown that Joubert regarded all the eastern Yünnanese limestones as Devonian. From a study of Leclère's fossils, Douvillé recognised that both the middle and upper divisions were represented. Lantenois' work confirmed this and also tended to prove that the lower division was present too. Deprat has mapped and subdivided the system in considerable detail. I have not seen any of these beds myself, for they occupy the region between the Triassic geosynclinal in the extreme south-east of the province, and the region of the lakes which I visited. Deprat relates that pure limestones are exceptional and due to local accidents, and that the deposits are usually composed of rocks of sandy, marly or shaley calcareous types. Both the lower Devonian and the Eifelian, and the Givetian of the middle Devonian are present, as well as the Frasnian and Famennian divisions

[1] Contributions to the Geology of the Province of Yünnan in western China. Notes on the stratigraphy of the Ordovician beds of western Yünnan, by J. Coggin Brown, with provisional palæontological determinations by F. R. Cowper Reed. *Rec. Geol. Surv. Ind.*, Vol. XLIII, Pt. 4, pp. 327-334.

of the upper part of the system. They are all very fossiliferous and the faunas show little variation from one point to another even over considerable distances. Like the Paudaukpin fauna of the Northern Shan States, the forms from the Yünnanese Eifelian show a close affinity with those of the same age from the Rhenish provinces of Europe.

To explain the absence of rocks of Devonian age to the north and north-west of eastern Yünnan we must be prepared to admit either that the Devonian was deposited therein and afterwards removed by denudation, or, that there was a break of sedimentation in these directions. Loczy recognised important and characteristic middle Devonian strata at Hoa-ling-pu in Ssu-ch'uan containing a fauna remarkable like the Yünnanese Meso-Devonian, whilst to the far west the very similar beds of the Shan States are found. It seems probable therefore that the first supposition is correct, and that the Devonian was removed by prolonged erosion towards the north and north-west, but towards the south-east this erosion was not experienced and consequently the entire sequence of the system is preserved.

Lower Carboniferous.

The earlier French workers soon recognised the presence of the Moscovian and Uralian, the Middle and Upper divisions of the Carboniferous in eastern Yünnan, but overlooked the Dinantian, the lowest division of the Carboniferous, and it was not until Deprat's recent survey took place that it was discovered in a few exposures to the north of Yünnan Fu, in the valley of the Yangtze Chiang.

Middle Carboniferous.

The Moscovian attains an exceptional thickness in eastern Yünnan. Lantenois was inclined to place certain beds containing *Spirifer mosquensis* Fisch. in the Uralian, owing to their analogy with the blackish limestones of Tongking, which Douvillé had already classed as Uralian after a study of their foraminifera, and in spite of the occurrence of the same species of *Spirifer* in them, the fossils being found in association at the Elephant Mount near Hanoi. Mansuy relying entirely on the presence of *Spirifer mosquensis* regarded them as Moscovian. This disputed question was finally settled in 1909-10 when Deprat and Mansuy discovered a series of Moscovian beds above the *Spirifer mosquensis* stage near Yünnan Fu.

The total thickness of these beds in eastern Yünnan is approximately 1,200 metres. The lower horizons are sandy and usually commence with a conglomerate. The higher horizons invariably consist of limestones, while between the two is found a sandy coal-bearing series with subordinate limestone bands.

The latest researches of the French geologists have shown that the Moscovian is best developed in the western parts of eastern Yünnan, that is to say to the west of the Pei-ta Ho. Further east only the upper part of the division exists and it rests directly on the Dinantian. This is a result of the movements which took place in Moscovian times along a line which was marked out after the Cambrian, resulting in the production of folds running in a north-east, south-west direction. In the western area the destruction of these folds produced the sandy sediments of the middle Carboniferous, but towards the east, between them and the south-eastern Chinese element of Bailey Willis, the detrital deposits were not formed and a stratigraphical break was thus produced. Local periods of stability in the west permitted the accumulation of limestones, and in the course of the period basic lavas were erupted which are now found interbedded with the upper portions of the series.

Upper Carboniferous.

Towards the end of Moscovian times a general slow submergence commenced with a consequent transgression of the sea. The higher lands forming the folded zone referred to above, were, therefore, not covered by the sea at the commencement of Uralian times, and for this reason there is some irregularity in the continuity of the first deposits. The transgression was gradually creeping on and with the second part of the Uralian was completed.

During Uralian, Artinskian and middle Permian times no appreciable earth movements took place and enormous thicknesses of limestones were laid down. In appearance they are so much alike as to be quite indistinguishable lithologically, but the beauty and variety of their foraminiferal remains has enabled a system of zoning to be worked out, which in the masterly hands of Deprat has proved to be the most detailed piece of geological work yet accomplished in China.

These immense limestone masses have largely made the scenery of eastern Yünnan what it is. In the case of the strongly folded middle Carboniferous of the region of the great lakes, the sandy

zones have given way quickly under the action of denudation, leaving the limestones exposed in great escarpments on the hill-sides, or forming the fine lines of the crests. But it is different with the Uralian and Permian limestones,—a series of some 1,500 metres in thickness without any intercalations of any sort, for erosion has affected them in other ways and scenery of a karstic type has been produced. As is only to be expected under such circumstances, the surface hydrography has been supplanted by an underground circulation.

The Permo-Carboniferous sea advanced to a considerable extent on the south-eastern Chinese element and covered what are now the Chinese provinces of Kuang-tung and Kuang-si as well as the greater part of Tongking. In all probability it also submerged much of the Indo-Chinese peninsula, south-western Yünnan and the Shan States. In this connection it may be mentioned that I have found Fusulina limestones in the neighbourhood of Pu-erh Fu in south-western Yünnan.

According to Deprat the lower Uralian limestones are characterised by *Fusulina* of the *Fusulina brevicula* and *Fusulina kattaensis* types, while *Neoschwagerina* is found in the upper divisions. In the Artinskian, which is in perfect conformity with the former, *Neoschwagerina* is also found. The middle Permian contains *Doliolina*, and the lowermost beds of the upper Permian have *Neoschwagerina* (*Sumatrina*) of the *Neoschwagerina multiseptata* and *Neoschwagerina Annae* types.

During the Artinskian and middle Permian no movements or changes of sea-level affected eastern Yünnan, and the limestones with their rich foraminiferal or brachiopod faunas were slowly deposited over the areas already occupied by the Uralian limestones. If Deprat is correct in considering that the limestones with *Sumatrina* belong to the upper Permian, then similar conditions prevailed throughout these times as well.

After this, a retrogressive movement set in, as Lantenois was the first to point out. The emergence of the land from the sea commenced with gentle folding, and quickly developed until the ocean had left its former basin, when denudation vigorously attacked the Permian and Uralian limestone masses. To such an extent did this proceed that in some places they were entirely removed, for Deprat has found sections in which the upper Permian sandstones rest directly on folded lower Devonian strata.

The folding which brought in these movements seems to have followed more or less approximately the direction of the older Moscovian folds, erosion was strongest in the east, and the sea was forced back far to the south and west.

Upper Permian Red Beds Series.

The deposition of the great Red Beds Series of Yünnan now followed, commencing with thick conglomerates and ending with red sandstones and shales which in many places contain salt and gypsum. The close of the Permian was marked by wide-spread basaltic and andesitic eruptions, the lavas of which attain an extraordinary thickness in the Yangtze Chiang valley both to the north of Ta-li Fu, and further east in the region of the great bend.

La Touche has already shown that the North Shan States were elevated above the level of the sea through Permian and Triassic times. The results of this great orogenic movement were also pronounced throughout western Yünnan, though perhaps not for so long a period, for I have found fossiliferous Triassic strata in the central and south-western parts of the province.

In the preceding paragraphs I have attempted to show briefly what its results were in eastern Yünnan, and I may conclude this section by a quotation from Bailey Willis, which goes to prove that our areas were merely acting their part in those great movements which definitely laid the foundations of the present mountain systems of eastern Asia in Permo-Mezozoic times :—

> "The diastrophic movements which occurred in all continents during the closing epochs of the Palæozoic and the initial epochs of the Mesozoic were pronounced and prolonged throughout Asia. They ultimately changed that face of the globe, as Suess has pointed out, welding together the separate elements of the Asiatic continent, except that the Angara and Gondwana lands remained separated by the Himalayan strait. In contrast to the gradual changes of level which had characterised the Palæozoic, these disturbances were of decided orogenic character. They gave rise to the mountain systems, which are structurally still the controlling features of Asia. The foundations of the ranges are now raised to the summits of the Tien-shan, Kuen-

> lung, and Ts'ing-ling-shan, and the substance of their masses constitutes the Triassic and Jurassic sediment of Asia. By Cretaceous time the continent was again low. In the zone of the great mountain chains of northern India, the Permo-Mesozoic movement was manifested in variations of sediment, not in folding."[1]

Triassic.

Strata of Triassic age were probably deposited over a considerable portion of Yünnan, but they are now only found in extremely limited areas, owing their preservation to faults letting them down and keeping them from the general erosion to which the province was severely subjected at the close of Pliocene times. In eastern Yünnan they occur in the extreme south-east and consequently out of the area with which this paper deals. They are mentioned here to complete this short account of the general geology of eastern Yünnan, but I shall deal with them more fully when I come to describe the Triassic beds mentioned above. The transgression of the Triassic sea covered a surface exposed to long erosion during the upper Permian, and it seems to have commenced with the formation of lagoon-like expanses, for the lower deposits according to the French workers, consist of alternations of beds with terrestial plant remains and others characterised by marine forms of life. The three great divisions of the Trias are represented and are well separated by distinguishing faunas. As a rule they are said to be very folded, often reversed and even inverted. The uppermost beds of the lower Trias have a littoral facies and the passage from the Werfenian to the Mesotrias is a progressive one. The Mesotriassic forms collected by Loczy at Tchung-tien in the far north-west are practically identical with those from south-eastern Yünnan, which tends to prove that similar conditions prevailed over a very extended area. Conditions entirely changed with the passage into the upper Trias, the deepening of the sea attained its maximum, pelagic conditions prevailed and an invasion of cephalopods, marked by the development of ammonites of the *Trachyceratidæ* family, took place during the Norian and the Carnian. A definite uplift set in during the upper Norian and sandstones containing coal seams with plant remains were formed. Similar conditions of a continental character probably existed

[1] Research in China., Vol. 2, p. 89.

during the Rhaetic, at any rate over eastern Yünnan. In the Shan States, marine or lagoon deposits were laid down, which may have extended some distance into Yünnan, though it seems proven that Rhaetic land comprised Ssu-ch'uan, Eastern Yünnan, Central China and parts of Indo-China.

Jurassic and Cretaceous.

Jurassic beds are known to occur in Ssu-ch'uan and in the northern Shan States, but no trace of them remains in Yünnan if they ever existed there at all. Bailey Willis has remarked that a geologist taught only by observation in China, outside Tibet, would know nothing of the Cretaceous.[1] No strata of this age have been found in Yünnan or the Shan States.

Tertiary and Pleistocene.

With the upper Trias marine sedimentation ceased and the only known deposits of a later age are fluvio-lacustrine or lacustrine beds of late Tertiary times. I have already described similar deposits of western Yünnan and it will suffice to state that those of the eastern part of the province differ in no essential features from them.

Himalayan movements.

But although unimportant from a stratigraphical point of view, these continental conditions witnessed epoch-making changes of a physiographic description. At a period which undoubtedly belongs to the early Himalayan phase, Yünnan and the Shan States were involved in far-reaching folding movements. Overthrusting was common and the Yangtze region in the neighbourhood of the great bend or what Deprat calls the southern prolongation of the Yun-ling-shan, was pushed forward on to the Yünnanese area further south. A long period of peneplanation followed, the Himalayan folds were subjected to denudation and planed away, and eventually great faults cut across the region, probably towards the end of Pliocene time. These faults formed most of the depressions, which during the period of stability which followed, gave rise to the lakes wherein the late Tertiary fresh water deposits were accumulated, and, at the same time the river valleys were filled in with thick sandy fluvial beds. The final phase is marked by a very decided uplift—a great period of general elevation, to which much of the present topography is due, the lakes were partly drained, and the existing hydrographic systems installed.

[1] Research in China, Vol. 2, p. 89.

The Cambrian Rocks.

Distribution and character of the Cambrian strata.

The Cambrian is only found in the extreme east of the area between the north-eastern shores of lake Yang-tsung and the hills to the east of the I-liang Hsien valley. It also reaches to the north of this town into the upper part of the tributary valley of the Chu-tsing Ho. All these exposures are in continuity and owe their origin to a great fault, which has brought them into contact on the west with the Moscovian horizons of the Si-yang and Eul-long-si-chou neighbourhoods.

The fault belongs to the group of parallel fractures which run roughly north and south and fracture this part of Yünnan.

Around I-liang Hsien the Cambrian strata consist of reddish sandy slates and sandstones with alternations of greenish slates, and lamellar, schistose, sandy beds with a few subordinate limestone bands. Their strike and dip is not constant and they are generally very contorted. The only fossils I found were—

Planolites
Redlichia sp. (fragmentary).

Supposed Cambrian beds between Lu fung Hsien, I-men Hsien and An-ning Chou.

Soft, variegated marls of light yellow and red shades, with harder bands of a pinkish phyllite are found between the villages of Lu-piao-kai and Pê-han-ch'ang on the An-ning Chou, Lu-fung Hsien route. They appear to strike north-north-east, south-south-west and to dip west-north-west at 40°, but are very contorted and crossed in every direction with thin quartz veins. On the west they are faulted against Permo-Carboniferous limestones and on the east against the Red Beds. Further to the south on the An-ning Chou, I-mên Hsien route, I again discovered a series of hard reddish slates, in the line of strike of the former outcrops. Alternating with them were bleached slates, quartzites, and multi-coloured bands of various blue and red tints. Contortion is very marked and the rocks seem to be bent and dislocated to an extreme degree. They stand out as a high ridge which attains an elevation of 7,800 feet, runs north and south, and is faulted against the limestone series on the east.

I was not able to find any fossils in these outcrops, perhaps owing to the intense metamorphism which they have undergone, but

I correlate them on lithological grounds with the Cambrian beds found further to the east, which they greatly resemble.

The Middle Carboniferous or Moscovian.

Strata of middle Carboniferous age are extensively developed in the Yünnan Fu neighbourhood, especially around the southern end of lake K'un-yang. The lower horizons usually consist of soft, reddish, unfossiliferous sandstones which have readily broken down under the influence of denudation, while in the upper zones limestones predominate.

Ch'eng kung Hsien, K'un-yang Chou route.

Good exposures of both kinds are to be found between Ch'êng-kung Hsien and K'un-yang Chou. Commencing from the former town, a road runs south and west, parallel to the eastern and southern edges of the lake and across the flat deposits which partially fill up its basin. In places these are pierced by middle Carboniferous sandstones and limestones, standing out like rocky islands above the flat surface of the plain. Near Chin-ning Chou, continuous exposures of red and white speckled sandstones strike north and south and dip towards the east at 65°, forming the northern extension of the great parallel north and north-easterly striking folds, shown by various French geologists to exist to the south between this area and Hsi-o Hsien. Above the speckled sandstones, outcrops of decomposed andesitic lavas are followed by thick limestone bands, weathered into buttresses and needles. These in their turn give place to quartzites and sandstones, alternating with arenaceous shales, and visible up to the town of K'un-yang Chou, when not obscured by the lacustrine deposits which appear to be thicker just here than elsewhere.

Middle Carboniferous of Eurl-kai.

Excellent exposures of the middle Carboniferous horizons are found at Eurl-kai, a small coal-mining locality situated a few miles to the north-west of K'un-yang Chou. For part of the way the lacustrine deposits of the lake basin hide all outcrops, until sandy yellow shales are found striking north 20° west, and dipping at high angles towards the east. They are followed by limestone bands which overlie them.

The following section is visible at the mines :—

	thickness.
(*d*) Dolomitic limestone	?
(*c*) Limestone with *Euomphalus*	10 feet.
(*b*) Sandstones with coal seams	40 ,,
(*a*) Reddish limestone.	?

The dolomitic limestone contains *Chaetetes subradians* Mansuy. From the Euomphalus limestone Lantenois had already obtained :—

Euomphalus sp.
Spirifer mosquensis, Fischer.
Athyris ambigua, Sow.
Orthothetes cf. crenistria, Phillips.

In addition to most of these I also collected

Bellerophon sp.
Murchisonia sp.

and numerous badly preserved corals probably referable to the genus *Cyathophyllum*.

Thin sections of the same rock examined under the microscope revealed the presence of—

Endothyra cf. Bowmanni Phill.
Fusulinella sp.
Spirillina sp.

Certain thinner limestone bands associated with (*d*), present a curious concretionary or oolitic structure. The matrix of the rock is clear calcite filled with small, dark patches of circular outline, often exhibiting a concentric structure and sometimes filled with clear calcite.

Lantenois has recorded four coal seams which were visible at the time of his visit, but I only saw two of these, each about four feet thick and separated by a thin series of sandstones and shales.

The strike at the mines is north-east, south-west, and the dip at a low angle to the south-east. In the hills to the north-west, I found horizon (*c*) again, certain bands of the rocks being full of a weathered brachiopod :—

Athyris ? sp.

Middle Carboniferous of Hai-kou and Hsin-ts'un.

The middle Carboniferous succession found at Eurl-kai is also exposed on both sides of the narrow valley of the P'u-tu Ho, which drains lake K'un-yang. Its occurrence therein is entirely due to the great depth to which erosion of the overlying Permian and Permo-Carboniferous limestones has been carried by the stream, helped by the late Tertiary earth movements which have resulted in the partial drainage of the lake.

From Hai-kou to Hsin-ts'un the coal-bearing sandstones can be seen high above the river, and they are doubtless prolonged further to the south-east in the direction of the lake. Near Hsin-ts'un I found the following sequence, the rocks themselves being almost horizontal :—

	thickness.
(*e*) Thick bluish-grey limestone	?
(*d*) Limestone with *Chaetetes*	?
(*c*) Limestone with *Euomphalus*	?
(*b*) Sandstones with coal seams	30–40 feet.
(*a*) Limestone	

(*c*) contains :—

Euomphalus sp.
Spirifer sp.
Cyathophyllum sp.

(*d*) contains *Chaetetes subradians* Mansuy.

The coal-bearing series at Yen-tzu-shao.

A few miles to the north of Yünnan Fu, the Uralian limestones which are found in the immediate vicinity of the city, give place to strata of Moscovian age, the coal-bearing series already described from the two previous localities being represented as follows :—

(*c*) White fossiliferous limestone.
(*b*) Sandstones and shales with thin coal seams.
(*a*) Sandy limestone.

The series is not very fossiliferous but from the white limestone (*c*), I obtained badly preserved specimens of the following genera :—

Euomphalus sp.
Athyris ? sp.
Zaphrentis ? sp.
Crinoid stems.

Thin sections of the rock show the presence of the following foraminifera :—

Fusulinella sp.
Spirillina sp.
Endothyra ? sp.

This limestone weathers into small cliff-like exposures which border the little Yen-tzu-shao valley on the east, and which are cavernous in their lower parts. The western side slopes down to a deep tarn, fed by a small spring from the rocks at the head of the valley.

The arenaceous succession at Yang-lin.

Between the village of Ma-po-tsun and Yang-lin, sandstones, quartzites and shales with decomposed lava beds underlie Uralian limestones. They are hidden to a great extent by the alluvial deposits of the Ma-po-tsun plain.

Middle Carboniferous of Si-yang and Ta-wa-tzu.

The middle Carboniferous is well seen in the mountain ranges which run north from the neighbourhood of the Yang-tsung lake. The northern part of the valley of the small stream which joins the Chu-tsing Ho at I-liang Hsien, is bounded on the west by a high and precipitous escarpment, in which rocks are exposed ranging from the middle Carboniferous to upper Permo-Carboniferous horizons. As is the case in other localities, the middle Carboniferous coal-bearing horizon occurs and the seams which it contains are actively exploited by Chinese methods.

At Si-yang, the northernmost point where coal is worked, the following series is exposed :—

(*h*) Hard, greyish limestone.
(*g*) Bluish dolomitic limestone.
(*f*) Greyish sandy shales with coal seams.
(*e*) Yellowish dolomitic limestone.
(*d*) Greenish shales.
(*c*) Thin limestone bands.
(*b*) Red shales.
(*a*) Limestones.

Horizons (*e*), and (*g*), contain—

Chaetetes subradians Mansuy.

From the green shales (*d*), I obtained—

Sanguinolites ? sp.
Allorisma sp.

There are two coal seams, the upper of which is five feet and the lower between seven and eight feet thick. Blocks of the yellow dolomitic limestone are common in the heaps of debris from the mines.

I made another ascent of the escarpment from Yang-kai to Ta-wa-tzu (elevation 7,300 feet). Here there are two coal seams and the same succession of limestone and shale horizons as found at Si-yang. The scarp itself runs north 20° east, and old coal workings extend along it for miles, confirming the continuity of the seams themselves. The strike at the Ta-wa-tzu mines is north 35° east and the dip westerly at 44°. Coming down the spur to Yang-kai, rough blocks of limestone from the heights above are strewn over the outcrops of the lower shale horizons.

The Yang-kai valley is filled with alluvium and has an elevation of 5,350 feet above sea-level. Along the road which leads southward to I-liang Hsien, scattered outcrops of greenish and bluish sandy slates belonging to the lower Cambrian are found. They are faulted against the Moscovian horizons exposed in the lower parts of the scarp. Certain bands in the slates are crowded with the supposed worm casts or trails, to which the name *Planolites* has been given, and I did not succeed in finding any other organic remains, though Deprat has lately recorded *Acrothele orbicularis* Mansuy from the same locality.

Middle Carboniferous to the north-west of Yunnan Fu.

Strata of middle Carboniferous age are found in the vicinity of Wu-ting Chou and between this town and Fu-min Hsien, following the main route which leads to Yünnan Fu from the ferry across the Yangtze Chiang at Lung-kai. I marched over this route from Hui-li Chou in Ssu-ch'uan, in May 1909, when owing to heavy and continuous rain, which made geological observations almost impossible, I was unable to examine the country in any detail. My general impression is that the middle Carboniferous rocks are found in broad synclines separated by Uralian limestones, and that the general strike is north-east—south-west. Owing to the absence of any fossils it is necessary to rely on lithological characters and stratigraphical position for the separation of the various groups. On the route map, accompanying this report, I have shown the whole area as undifferentiated Carboniferous, though it is possible that some of the reddish sandstones

and shales belong to the upper Permian and not to the middle Carboniferous.

Entering the sheet towards the north-west, near the town of Yuan-mou Hsien, the road crosses strata of the upper Permian "Red Beds" series, to a point some three miles beyond the village of Hua-ch'iao, where outcrops of igneous rocks are seen. These are probably of upper Permian age, and attain a considerable development in the immediate neighbourhood, the paving setts of the mule road and the stones used in the construction of walls, being obtained from them. About this point the road which has hitherto proceeded almost due east, commences to turn towards the south and continues approximately in this direction until Yünnan Fu is reached. On the top of the hill above Yu-ying-tang, there is a small outcrop of limestone, overlain by greenish shales, and halfway between the villages of Tang-pa-shao and Wu-lung-tung, hard, dark blue limestones are found. These belong either to the Permian or Permo-Carboniferous, and are underlain by reddish sandstones and green shales, which continue past the town of Wu-ting Chou as far as Leng tsun, where they are replaced by black shaley bands, only to reappear again further to the south in the low rounded hills over which the road undulates. In one place I observed a thin bed of marly bluish limestone full of small gasteropods, which it was impossible to collect as they smashed evenly with the rock.

At the top of the ridge, close to the boundary between the districts of Wu-ting Chou and Yünnan Fu, Permo-Carboniferous limestones crop out, but from this point as far as the town of Fu-min Hsien, sandstones and shales predominate The route still keeps to the south, and after crossing a minor watershed between Chê-pê and Chang-wan, descends the tributary valley which meets the main stream from the K'un-yang lake, flowing north to join the Yangtze Chiang. At Nan-ying, broken red sandstones and shales strike north-east, south-west and dip south-east at 80°. Fu-min Hsien is a small, walled city situated in an old alluvial filled lake basin. To the west, jagged limestone peaks are visible, and towards the south near Sha-ko-tsun, I found small isolated exposures of fossiliferous limestone of Uralian age, which with an interbedded lava flow become better developed as the road slowly ascends the tributary valley leading from the plain. They are underlain by massive, white and greyish-white,

and thinner, reddish, shaley sandstones which near Erh-tsun strike north-east, south-west and dip north-west at 40°. These rocks belong to the middle Carboniferous and are in the direct line of strike of the fossiliferous strata of the same age which I found at Yen-tzu-shao, a few miles away to the north-east.

Middle Carboniferous of Tsi-tien and Ho-shui-tang.

The middle Carboniferous is well developed in a synclinal fold, bounded on the east by the fault which forms the western shores of lake Yang-tsung, and on the west, according to Deprat, by another fault which brings it into contact with the Georgian, characterised by *Redlichia chinensis* Walcott. In the course of my own traverse across this region I was unable to come to any conclusion regarding the age of the beds immediately to the west of the middle Carboniferous outcrops, owing to the absence of sections along the track I followed and my inability to leave it to look for them elsewhere. Deprat's more recent detailed survey has however settled the matter.

The best sections of the middle Carboniferous beds themselves are obtained in the hills to the south of the eastern end of the small Tsi-tien valley, close to the abandoned coal mines of Hoshui-tang. At this place the following succession exists :—

(*i*) Limestone with corals	Thin.
(*h*) Bluish white shales	
(*g*) White calcareous sandstones	
(*f*) Coal seam	
(*e*) White sandstone	
(*d*) Hard porcellanous limestones	100 feet approx.
(*c*) Dolomitic Limestones	
(*b*) Decomposed, andesitic lava flow	50 „ „
(*a*) Red sandstones	Base not seen.

From (*i*), I obtained :—

Cyathophyllum sp.
Zaphrentis ? sp.
Bellerophon sp.
Euomphalus sp.
Crinoid stems.

From (*c*) and (*d*) :—
Chaetetes subradians Mansuy.

According to Deprat, the coral limestone at the top of this series is overlain by a further 600 feet of limestone which contains

a rich gasteropod fauna, while above these the grey limestones of the lower Uralian are found.

Limestones of this age outcrop on the steep ascent from lake Yang-tsung to Tsi-tien, and I found good exposures in the cuttings of the railway, then under course of construction. At the point where the route from Tang-chi crosses the line I obtained the following fossils :—

Cyathophyllum ?
Fusulina sp.
Dielasma sp.
Athyris cf. subtilita Hall.
Murchisonia laevigata Mansuy.
Naticopis sp.

In addition to these the limestone contains abundant Polyzoan remains. The horizon appears to belong to the uppermost part of the middle Carboniferous.

General remarks on the middle Carboniferous.

The base of the middle Carboniferous is not visible in any of the sections which I have examined. According to Deprat the lowest horizons are to be seen further south at Sin-chai, Jê-ma-chong and Cha-chong, and the whole group can be divided as follows :—

Upper Limestones.
Coal bearing beds with *Spirifer mosquensis.*
Upper Sandstones.
Lower Limestones.
Lower Sandstones.
Conglomerates.

The Permo-Carboniferous and Permian Limestone Group.

General remarks.

As far as the region which I traversed myself is concerned, it is difficult, if not impossible to distinguish lithologically the upper Moscovian limestones from the lower Uralian ones, or, indeed from the Permian limestones of the Artinskian and higher divisions which conformably follow them. At the same time the sandy coal-bearing horizons of the Moscovian, are strikingly different from the higher, thick limestone horizons. The latter are characterised by the presence of *Fusulinidae* which are sometimes found in enormous numbers

in certain bands. Further than this my own field work did not go, but it is necessary to mention the fuller interpretation which has lately been given by the more extended surveys of Deprat and his colleagues, regarding part of the area near Yünnan Fu across which I marched, and also the adjoining districts further south and east. The following quotation shows the importance of the middle Carboniferous uplift in Eastern Yünnan with the transgression of the Uralian sea which followed it across the earlier land surface, and finally proves that the general separation of the two groups which I had already indicated, is in reality a stratigraphical break of the first magnitude.

"Il appert donc que pendant le Moscovien une partie du Yünnan, la partie située à l'E. du Tié-tchen-'ho, (Ta-ch'iang Ho), s'est relevée avec formation d'un bourrelet plissé sur son bord occidental, bourrelet orienté N. N. E., pendant qu'à l'O. les sédiments gréseux s'accumulaient dans la dépression qui le bordait et s'étendait probablement très loin vers l'O. Mais on ne doit pas en conclure que la partie relevée s'est trouvée émergée pendant toute la période, et les lambeaux moscoviens disséminés ça et là, comme celui de 'Hoa-keuou par exemple, indiquent qu'à certains moments la mer qui battait à l'O. le bourrelet plissé faisait des incursions à l'E. de ce bourrelet. Ainsi se sont déposés les calcaires noirs de 'Hoa-keuou, les calcaires gris du Lo-atien, tandis que manquent les séries gréseuses; puis, il y a eu émersion temporaire pendant qu'à l'O. se déposaient les calcaires à *Fusulina brevicula*, ceux à *Fusulina Tchengkiangensis*, ceux à *Fusulina kattaensis*, dont l'ensemble atteint prés de 500 metres et qui manquent d'un façon absolue à l'est. Cette, période a vu la pénéplanation de la région située à l'E. du Tié-tchen-'ho, puis la mer ouralienne est revenue sur cette zone aplanie où tous les plis étaient décapés, recouvrant tantôt un étage dévonien, tantôt le Dinantien ou un horizon moscovien là où les circonstances avaient permis à l'érosion de les laisser subsister; plus on avance vers le N. vers Lou-léang et plus la transgression ouralienne se fait tardive; aux environs de Tien-sen-kouang par exemple ce sont les calcaires à *Schwagerina princeps*

Ehr. qui reposent directement sur les terrains envahis, tandis que dans la région de Mi-leu c'est par un horizon, moins élevé, celui à *Fusulina multiseptata* que débute le Supracarbonifère."[1]

The sub-division of the Permo-Carboniferous and Permian limestones.

Deprat has divided the Uralian limestones of eastern Yünnan into ten distinct horizons each characterised by a definite species of *Fusulina*, *Doliolina*, *Schwagerina*, or *Neoschwagerina*. The whole series is said to have a thickness of almost 800 metres but to be very irregularly distributed in different localities. In perfect continuity with it another calcareous series is found, though it is not represented in the special areas with which this paper deals. It contains a rich brachiopod fauna, the majority of the species being characteristic forms of the upper parts of the middle Productus Limestone of the Salt Range. Following Tschernyschew this is regarded as Artinskian. The Artinskian limestones are conformably overlain by another thick limestone series which contains the foraminifera *Doliolina lepida* in abundance, as well as numerous new species of *Fusulina*. According to H. Douvillé these indicate a middle Permian fauna. Limestones with *Neoschwagerina* rest conformably on the latter horizons and are correlated with the upper Permian. In most localities where the other beds of the Permian are exposed the latter have been removed by the action of the powerful denudation which set in at the close of Permian times, when a retrogressive movement of the sea took place.

Development of the Uralian around Yunnan Fu.

I first met with the Uralian limestones on the road between An-ning Chou and Yünnan Fu. This route approaches the provincial capital from the south-west, and for a few miles beyond the former place crosses the red shales and sandstones of the upper Permian Red Beds series. Near the village of Tzu-men-lu, small, isolated outcrops of hard bluish-grey limestone pierce the red soil. They are fossiliferous and contain foraminifera which I provisonally determine as:—

Fusulina regularis Schellw.
Fusulina brevicula Schellw.
Bigenerina sp.
Endothyra sp.

[1] *Loc. cit.*, p. 125

According to Deprat's classification these species are characteristic of the lowermost Uralian, and on stratigraphical grounds I believe this is correct, considering the close proximity of the Moscovian beds further south and the absence of faulting between. The limestones are followed by red shales which are well exhibited near Tu-shu-pu. The northern boundary ridge of the small valley through which the route runs, seems to be entirely made up of limestone, which forms cliff-like exposures building the steep sides of the range. The flat lacustrine deposits which mark the former extension of lake K'un-yang are met with after descending the pass at Pi-chi-kuan[1], and are seen to be edged with limestone cliffs. The only fossils I succeeded in obtaining from any of these exposures near the road were crinoid stems and

Bellerophon sp.

I am convinced from their position that these rocks represent a lower Uralian horizon.

The north-western shore of lake K'un-yang is bounded by the high limestone cliffs of Sin-chang, which attain an elevation of 8,500 feet above the sea. I was unable to examine these magnificent exposures, though Lantenois had already pointed out that both Carboniferous and Permian horizons would certainly be found therein. According to Deprat who has succeeded in going over the ground, at least 400 metres are composed of Uralian limestones, which he divides into six horizons each characterised by a definite *Fusulina* fauna. The upper parts of these great cliffs are built up of limestones of lower and middle Permian age which conformably follow the Uralian ones.

The K'un-yang Chou, An-ning Chou, I-men Hsien area.

The region lying between the western shores of the lake and the An-ning Chou, I-men Hsien route is to a great extent occupied by Permo-Carboniferous limestones. At the top of the ridge to the south of the former town, greyish-white limestones crop out from under the red beds which here dip at low angles to the north-east From them I obtained :—

Fusulina sp.

Lingulina sp.

The region to the south of the lake, and that bordering on Eurl-kai is occupied by middle Carboniferous beds exposed by the removal of the thick limestones which once covered them.

[1] A thin band of decomposed andesite occurs in the Pi-chi-kuan pass. It is too small to be shown on the map.

The area north of Yünnan Fu.

North of Yünnan Fu, the Permo-Carboniferous limestones are found in the anticlines of the great north-east, south-west striking folds which are here so well developed. At Sha-ko-tsun, to the extreme east of the Fu-min-Hsien plain, I recognised greyish-white fossiliferous limestones containing small brachiopods and

Neoschwagerina aff. craticulifera Schwager.
Lingulina aff. Szechenyi Lor.
Margaritina ?

These foraminifera prove that the horizon belongs to the upper Uralian.

Similar limestones form small cliffs along the valley followed by the road from Fu-min Hsien to Yünnan Fu. Further south they are replaced by Moscovian beds, which in their turn give way to the Permo-Carboniferous limestones on the steep ascent above Li-tzu-ping. In this neighbourhood the country is very wild and rocky and plentifully covered with thin pine forest. The rivers cut narrow, deep gorges, and in one place a small stream goes straight through a narrow spur in an underground channel. The ascent continues over similar rocks to Hsiang-kan-chiang, elevation 7,100 feet, and then descends to the Yünnan Fu plain at Pu-chi.

On the north and north-east of this plain large expanses of country are covered with the Uralian limestones. They form the high and picturesque peaks crowned by temples, which over-shadow the northern end of the plain, and within the walls of the city itself, near the northern gate, pierce the thin covering of soil in small exposures, a diligent search in which failed to reveal any trace of recognisable organic remains. Again, between Yen-tzu-shao and Yang-lin, I found them in well-marked bands striking north-east, south-west and dipping at high angles to the south-east. To the east of the route which runs from Yünnan Fu to Sung-ming Chou, pale, greyish-white limestones with *Fusulina* strike north 30° west and dip to the south-west. In places this district has quite a karstic appearance, water is scarce, valleys of enclosed drainage and small pot holes are common.

North of I-liang Hsien

To the north of I-liang Hsien, the higher parts of the spurs which I have already described in the section of this paper devoted to the middle Carboniferous beds, are made up of Permo-Carboniferous limestones

which capping the heights at Eul-long-si-chou and Si-yang and continuing north-east, attain a height of 7,500 feet at the point where they are crossed by the Yang-lin, I-liang Hsien route.

Around lake Yang-tsung.

The north-western corner of lake Yang-tsung is occupied by a synclinal fold formed of limestones of the same age, on both limbs of which middle Carboniferous rocks are found. They are well exposed on the steep hill side which rises above the western shores of the lake, and which culminates in the heights of Ho-shui-tang.

The Upper Permian Red Beds Series.

Contrast between the Permo-Carboniferous and upper Permian.

The red sandstones and shales of the upper Permian present the greatest possible contrast to the thick, massive and perfectly conformable Permian and Permo-Carboniferous limestones which underlie them, and mark a complete change which at this period affected not only Eastern Yünnan, but the central and western parts of the province too, for I have proved their extension into the far west. After the deposition of the limestones with *Neoschwagerina* of the *Sumatrina* group, which according to Deprat belong to the lower Thuringian and are comparable with the upper beds of the Productus Limestone of the Salt Range, an extended uplift took place resulting in the exposure of the great calcareous series to profound denudation, and the subsequent deposition of conglomerates and red sandstones on various horizons of the lower rocks. The stage in which this intense peneplanation and deposition of conglomerates and coarse sandstones took place, was succeeded by another, but very much smaller transgression of the sea, which formed lagoon-like expanses in which the salt and gypsum-bearing marls of the upper Permian were laid down. This was again followed by another uplift, characterised by further erosion and later by extended and very pronounced volcanic action.

Distribution of the Red Beds Series.

The Red Beds are only found in the west of our area where they occupy the whole of the country around the cities of Yuan-mou Hsien, Lu-fung Hsien, Lo-tzu Hsien and An-ning Chou. Further west

still, as I hope to show in a later paper, they attain a greater development especially around the salt producing districts of central Yünnan.

Traverse across the Red Beds between Yuan-mou Hsien and Wu-ting Chou.

This route enters Sheet 31 N. E. near Yuan-mou Hsien and proceeds in an almost due easterly direction across the Red Beds for about 30 miles. The structure appears to consist of rather broad folds, the axes of which as a rule strike north and south, but occasionally north-east, south-west. Just above the village of Ma-tou-shan, fine-grained, red, laminated sandstones strike north-east, south-west, and dip north-west at 47°. From this place there is a steep ascent to Cha-fang, along the side of a narrow and very deeply excavated valley, for the soft sandstones and shales which form the prevalent rocks of the group, are readily denuded and quickly removed by the continued action of running water. Near Cha-fang, which has an elevation of 7,300 feet above sea level, red and green shales strike north and south, and the same strike is found in all exposures as far as Hsi-jên-hsin (8,150 feet), where the dip is towards the east at 60°. To the south of Cha-fang and in the bottom of the narrow valley, lies the village of Hsiao-ching which possesses salt mines and brine wells where the manufacture of salt is carried on. Leaving Hsin-jên-hsin the road crosses fairly level country for a few miles before descending to Shih-la-ta and Ma-an-shan. The latter place lies in a small hollow, a shallow depression, the bottom of which is cultivated with assiduous care and is in marked contrast with the low, pine-clad hills which surround it. These hills are largely made up of red and speckled sandstones striking north-north-west, south-south-east and dipping east-north-east at 45°. There is now a slight descent to the main branch of a small, independent tributary of the Yangtze Chiang, (which is only some 25 miles away to the north in a straight line), the banks of which are covered with good arable land, an occurrence rare enough to be well worthy of notice. The ascent from this valley is to the east, along the north bank of a small tributary of the main branch, passing villages such as Hai-tzu and Lu-ch'u-pê, surrounded by little patches of cultivation, and separated by spurs on which reddish or yellowish or greenish shales, or soft-speckled, or fine-grained red sandstones crop out.

Rarely, the sandstones are harder and form steep bluffs on the hillsides. One mile beyond Hai-tzu, broken red shales strike north 10° west and dip towards the west at 53°. Four miles beyond the village of Hua-chiao, exposures of a fresh augite andesite were found.

The Red Beds around An-ning Chou and Lu-fung Hsien.

Small outliers of the Red Beds series between Yünnan Fu and An-ning Chou, show sections of the basal conglomerate resting on the eroded surfaces of the lower Uralian horizons. To the west of the latter town, good sections of the lower portions of the series are obtained, consisting of reddish-yellow and violet shales and sandstones which strike slightly to the east of north and dip towards the east. There are few exposures between Tsao-pu-kai and Ching-lung-shao, though near the latter village thin laminae of a marly nature were discovered interbedded with hard red shales and associated with bands of a porcellanous variety of quartz. Near Lu-piao-kai, thin red sandstone bands striking north and south and dipping west at 15°, are followed by the older metamorphosed rocks described earlier, which extend for about five miles and are faulted on the west against Uralian limestones, which in their turn are followed by the conglomerate marking the base of Red Beds series. Quartz pebbles predominate in this conglomerate but limestone ones also occur. At this point the road leaves its formerly westerly direction and begins to turn towards the north. Owing to the absence of trees and soil in the Yao-kuan valley, excellent exposures of the strata are obtained and the separate bands of the Red Beds series, each of a bright and distinctive tint can be traced across the hills surrounding the valley for some distance. The strike is approximately north and south and the dip 18°-20° to the west. These rocks are succeeded by thick red sandstones and by conglomerates towards Lu-fung Hsien, where they disappear beneath the lacustrine deposits of the plain, which has an elevation of 5,300 feet above the level of the sea. It is bounded on the west by steep north and south running ridges rising to heights of over 8,000 feet, and mainly composed of reddish shales and sandstones. Below these I found a few outcrops of contorted phyllites which are probably brought up by faulting, but they occupy too small a space to be shown on the map.

Late Tertiary and Quaternary.

Identity of these deposits in Eastern and Western Yunnan.

The late Tertiary and Quaternary lacustrine and fluvio-lacustrine deposits of Eastern Yünnan do not differ in any way from those of other parts of the province, some of which I have already described in the first paper of this series.[1] The lake basins were formed towards the close of Pliocene times, during the great faulting movements which then took place, and the processes of deposition have been rapid and extensive ever since, as would naturally be expected from the great differences in elevation which must have resulted, and which is abundantly confirmed by the character of the deposits themselves. These consist of monotonous repetitions of sand-rock, sands, pebble-beds; and clays, often with patches and bands of impure lignite, the whole series bearing unmistakeable evidence of deposition by swiftly moving streams and torrents, and is badly adapted for the preservation of organic remains. The present lakes are very often merely the remnants of much more extensive sheets of water, and, in some cases, only the deposits themselves remain to show their former existence.

Distribution and prevalent lithological types in Eastern Yunnan.

Lacustrine and fluvio-lacustrine deposits, then, are found making up the flat ground on which the towns of Fu-min Hsien, Lu-fung Hsien, Tang-chi and Yang-lin are situated, while the great plain which stretches to the north and east of the K'un-yang lake originated in the same manner. It contains the towns of Yünnan Fu, Ch'eng-kung Hsien, Chin-ning Chou and K'un-yang Chou. The surfaces of the plains are in every case given up to rice cultivation, and it is often as impossible to draw a line between the recent and the Pleistocene deposits, as it is between the latter and the Pliocene ones which come below them.

The prevailing types in the case of the Lu-fung Hsien plain consist of soft, yellowish, sand rock with subordinate pebble beds; near Yang-lin of soft, yellowish sands and clays which are contorted in places; in the case of the Tsi-tien plain of black, reddish and bluish-white clays and thin seams of lignite. The contortion and bending of these beds in some places is particularly interesting, as it proves that they were laid down before the epeirogenic

[1] *Loc. cit.*, p. 199.

uplifts which ultimately resulted in the country attaining its present elevation.

In only one case did I succeed in obtaining any fossils from these deposits, and this was from a lake terrace in the neighbourhood of K'un-yang Chou, where abundant remains of a species of *Margarya* (*M. melanoides* Nevill), still living in the lake were found.

Late Tertiary Movements in Eastern Yunnan.

Importance of physiographic studies.

The interpretation of the Tertiary and Quaternary continental history of China is largely due to the physiographic studies of the American school of geologists, and the first connected account of this history so far as central and eastern China is concerned has been given by Bailey Willis [1]. By the application of similar methods Deprat has proved that the broad sequence of the chief events which have taken place in Yünnan during the same periods has been much the same. In a later paper I hope to bring forward evidence to prove that Western Yünnan and the Shan States of Burma played their parts in the same movements, but it will be helpful to summarise briefly the conclusions of the American and French geologists here, as they have a very important bearing on the question of the formation and filling up of the Tertiary lake basins now under consideration.

Summary of the American view.

Bailey Willis' views are best given in his own words,—

"With the epoch of mid-Tertiary folding the compression of Asia ceased for a time at least. The flat Hundes sandstone has its equivalents in the essentially flat Pliocene and Pleistocene deposits of Central Asia and Siberia. The record is one of erosion and wide-spread deposition in basins, either lacustrine or arid, and on fluviatile plains. But diastrophic movements have not ceased; they have taken on the form of normal faulting, involved in spreading of the continent, and the major features are accented by the fractures. These phenomena, which are extreme effects of vertical warping are chiefly of Pleistocene age. . .

[1] Bailey Willis. Research in China, Vol. 2, pp. 96-113.

I proceed to consider the evidence of orogenic movements other than folding; it is subordinately stratigraphic and predominately physiographic. . . .

Warping, that is, nearly vertical displacement of different parts of the surface to unequal amounts and often in opposite directions without dislocation, has been a general effect of diastrophism, especially during the later Tertiary and Quaternary. And the displacements have been so conditioned in time and place as to give rise to cycles of erosion, which can be distinguished in the plains, plateaus, ranges, and rivers of the continent.........Four phases are distinguished—the first or oldest is a peneplain, a very ancient and also very aged form, which is known from various parts of northern Asia, and a remnant of which we named from its preservation in the highest dome of the Wu-t'ai-shan, the Pei-t'ai form, developed during the Pei-tai cycle.

The next younger is a surface of mature erosion, which replaced any older features in most of the areas we saw. It is a surface of moderate relief, characterized by wide valleys and hills rarely a thousand feet high. It is typically developed near T'ang-hien, Chi-li, and we call it the T'ang-hien stage.

The third phase was one of aggradation in North China, the time of the early loess deposits. The moderate relief of the preceding stage was to a notable extent buried beneath the Huang-t'u, a formation consisting of wind-sorted waste from the deserts of Central Asia, whence the dust was brought chiefly by rivers. The partly buried hills along the western margin of the Great Plain of eastern China afford an illustration of the aspect of Chi-li, Shan-si, and northern Shen-si at the time. The great mountain ranges had not attained their present height. Attributing the desert waste to the climatic change from Tertiary to Pleistocene, which may have become effective in late Pliocene to the extent observed, we assign this phase to that time and to the opening of the Pleistocene. We designate it the Hin-chou stage, after the Hin-chou loess basin in Shan-si.

The fourth and present physiographic stage we named for North China the Fon-ho, from the river of that name, which, though older than the Fon-ho epoch, still flows through Shan-si among characteristic features of that stage. For South China, where the physiographic relations are somewhat different, we applied the name Yang-tzi to what is very nearly or precisely the same time division. It is an epoch of very decided mountain growth in China ; and if, as I believe, the principal continental upwarp of Central Asia is largely of the same date, it is the time of one of the most remarkable diastrophic movements of which we have knowledge. It appears to fall chiefly within the Quaternary, but may extend back into the Pliocene. The typical features are warped and faulted surfaces, which result from downward and upward movements of adjacent masses that underlie basins and graben or constitute plateaus and mountain ranges. The amount of sculpture is relatively slight, but great cañyons like the Yang-tzi gorges have been cut by antecedent rivers."

The French adaptation of the American view to Yunnan, with some observations on it

The divisions adopted by Deprat in Eastern Yünnan, and their relationships with those established by Bailey Willis are given below, together with a few personal observations on them.

1. Ancienne peneplain tertiaire posthimalayenne.

Etage du Kiao-ting-chann, corresponding with the Pei-t'ai stage. Age late Miocene and early Pliocene. I have not seen the remnants of this old peneplain in Eastern Yünnan, where it is only found at considerable elevations in the Kiao-ting-shan massif to the west of Tong-chuan Fu. The flat eroded folds of the eastern portion of the plateau of the Northern Shan States afford a good illustration of it.

2. Cycle d'erosion anterieur aux fractures pliocenes.

Etage du Tsouei-wei-chann, corresponding with part of the Tang-hien Stage. Age, late Pliocene. The wide valleys formed during this stage have resulted in the more or less complete removal of the ancient peneplain formed during Stage 1. The remains of Cycle 2 are well seen in the regular line of rounded summits bordering lake Yang-tsung on the west, between Tsi-tien

and Chin-ning Chou, and in the higher parts of the valley of the stream which drains lake K'un-yang. They have attained their present elevation as a result of the movements which took place in the later stages.

3. Periode de fracture.

Grouped with the Tang-hien Stage and corresponding with the late Pliocene. The period of erosion in Stage 2 was abruptly terminated by the formation of great faults, which let down considerable stretches of country and cut up the advanced topography which was in the process of production. These faults were the direct cause of the formation of the numerous lakes of central and eastern Yünnan numbers of which have since been drained. The remarkable faults which traverse the western part of the plateau of the Northern Shan States appear to me to have been formed at this period. The lacustrine deposits which fill up certain lake basins in the Shan States are identical in every respect with the Yünnan formations.

4. Cycle d'accumulation de Lin-ngan.

Etage de Lin-ngan, corresponding with the Hinchou Stage. Age early Pleistocene. During this stage the lake basins were rapidly filled in with fluvio-lacustrine deposits, which seem to have been obtained in great part from loess. Regarding the formation of this material Bailey Willis, after discussing Richthofen's theory, writes,—

> "At the present time we may supplement his hypothesis by adding to the continental causes connected with mountain growth those general causes of climatic change. which are believed to have initiated the cold climate of the Pleistocene.
>
> Believing that, toward the close of the Tertiary, there was a notable change of climate resulting in pronounced aridity in the interior of Asia, we find therein a sufficient explanation for the destruction of the vegetation and the removal of the mantle of decayed rock. The change is thought to have been one from a mild moist climate to cold arid climate. Glaciation is excluded by the absence of any deposits, such as would undoubtedly have remained as records if glaciers had developed far beyond the high mountain ridges in which they are now found. The degree of dessication is thought to have been sufficient to give the wind that power which

it now possesses as a sorting agent, in those regions where vegetation does not clothe the ground. It does not appear that this necessarily implies a desert condition, since at the present time, in northern China, where crops are successfully grown in many districts every year and in most districts three years out of five, the dust storms produced by the wind have a notable effect in resorting and redistributing the loess. The degree of aridity essential to efficiency of wind action is not inconsistent with the continuance of constant streams in larger watersheds. Under these conditions of effective wind action during a longer or shorter arid season of each year, and of effective erosion and transportation by water during the corresponding season covering the remainder of the year, that is, under climatic conditions similar to those now existing throughout a large part of eastern and northern Asia, both wind and water must have taken part in handling the available detrital material. During the dry season wind would be most effective, and the transported product would be that which was fine enough to be taken up by moving air. During the wet season torrential rains would gather the coarser products of rock decay, and, in brief hours of activity, transport them in large quantities to alluvial cones at the mouths of gulches. In the wide valleys, as on the mountains, the alluvium of the streams would be assorted by the winds and distributed, and the dust accumulations, spread by the winds in the basins and mountain slopes, would be taken up by the waters and redistributed as alluvium. These are the processes which are now interacting in the loess Basins of Shan-si, and the results are modern deposits of the Huang-t'u formation which are indistinguishable in lithologic character and structure from the earliest deposits which we saw.

Von Richthofen's theory of the loess does not admit the interaction of winds and streams. He held that during the loess epoch dessication was so complete that the rivers ceased to flow, and wind alone was the sorting and transporting agency. From this extreme view we

differ in assigning to rivers a practically continuous, though variable, activity as transporting agents. Had there been times of desert dryness, we should have deposits of desert sands and residual sheets of stony shingle, but these have not been observed in Chi-li or Shan-si."

The action of prevailing winds in Eastern Yunnan at the present day.

These processes are in full operation in eastern Yünnan to-day. During the dry season, which lasts from the beginning of November to the latter half of May, the soil becomes exceedingly dry, while water is so scarce that cultivation is hardly possible except in the old lake basin floors. At the same time a strong prevailing wind blows almost daily and carries with it enormous quantities of dust and fine rock debris, which are deposited in the dry stream beds and other favourable situations. I have very vivid recollections of the march between Tsi-tien and Cheng-kung Hsien in March 1908, when this wind blew with cyclonic force, and the clouds of dust which came along with it at regular intervals were thick enough to hide the surrounding landscape for the time being, the force with which the fine mineral particles were being propelled was quite sufficient to sting the face and injure the eyes. Between June and September, heavy rains set in which transport the dust accumulations to the lake basins. Deprat has recorded how he witnessed the rapid growth of the debris cones washed down into the Yang-tsung lake during a wet season which he spent on its shores.

5. Soulevement epeirogenique et cycle du Kin cha-kiang.

Etage du Kin-cha-kiang equivalent to the Fou-ho Stage. The events of this stage were produced during Pliocene times and are also in operation at the present day. According to Deprat this stage is characterised by a general wide-spread uplift, accompanied with the production of folds during which Yünnan attained its present altitude, and the actual hydrographic systems were established. The tributaries of the larger rivers captured the lakes and emptied them wholly or in part, at the same time erosion vigourously attacked the edges of the escarpments bounding the great wedge-shaped masses of the regions which had been vertically displaced at an earlier stage. The excavation of the enormous valleys which dissect the surface of Yünnan and Eastern Tibet also

took place. By a study of the local events such as the shape of the deep cañon-like valleys which drain the lakes of eastern Yünnan, Deprat has shown that this stage can be sub-divided into five distinct successive sub-phases each separated by intervals of stability.

Conclusions.

If the results of these physiographic studies are correct, as I believe them to be, it follows that both the great height of the Yünnanese mountain ranges and the development of the present drainage systems are in a great measure due to these Quaternary epeirogenic movements. Such a conclusion brings Yünnan into line with the rest of Central and Eastern Asia, for W. M. Davies and Bailey Willis have shown that it is impossible to account for the existing topography of these regions without invoking the action of such late epeirogenic movements.

The whole of farther India and Indo-China have also been subjected to the action of similar forces. The deep valleys of the larger rivers of the Shan States which are excavated in an old denuded surface, and the tilting of the Plio-Pleistocene lake deposits are amongst the more obvious results. The entire surface of Tonking is said to prove the existence of recent elevatory movements, to which the present drainage systems sculptured in an old surface is due, the young valleys of the Red and Black Rivers forming marked contrasts with the rounded forms of the higher lands. The raised beaches found at points so far apart as the Arakan Coast of Burma, and at Thanh-hao, now eleven kilometres from the shores of the Gulf of Tonking, both of which contain species still living in the surrounding seas, prove that these great elevatory movements have not yet ceased.

EXPLANATION OF PLATE.

PLATE 4.—Geological Map of the Country around Yünnan-Fu. Scale 1″ = 4m.

NOTE ON A DYKE OF WHITE TRAP FROM THE PENCH VALLEY COALFIELD, CHHINDWARA DISTRICT, CENTRAL PROVINCES. BY CYRIL FOX, B. Sc., M.I.M.E., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With text figures 2 and 3.)

During the field-season 1911-12 my attention was called to a "white clay dyke" in the Pench Valley Coalfield by Mr. G. F. Adams, Chief Inspector of Mines in India, and a few days later Dr. L. L. Fermor and I were able through the kindness of Mr. A. H. Parry of Messrs. Shaw, Wallace & Co. to visit the exposure in Barkui colliery.

The interest of the dyke lies firstly, in its being, so far as is known,[1] the only recorded "white trap" dyke in India; secondly, in its probable Deccan Trap age; thirdly, in its faulted occurrence in the mine; and fourthly, in the inferences that can be drawn from an examination of the specimens which were very kindly collected and forwarded by Mr. Parry.

The dyke is seen to be intrusive into a coal-seam in the east district of No. 4 mine in Barkui colliery. It is deeply altered, much fissured and as soft as cheese. The colour is a rich cream to pale apple-green or to a dark-green in the middle of the dyke, where it is about 4 feet across. The thickness, however, varies from 1 to 4 feet. The strike trends roughly from east-north-east to west-south-west with the dip steeply to the north. The associated coal-bearing strata have a gentle dip to the north-east. The dyke splits into two and thins rapidly when traced to the west-south-west and is cut off at both ends by faults in this district of the mine.

An examination of the coal at its contact with the dyke shows a very slight amount of coking: it is much impregnated with iron pyrites and calcite and is evidently a plane for the percolation of underground water. At the time of our visit this water had a distinctly brackish taste.

[1] Since the above was written Mr. F. L. G. Simpson of Mohpani has also sent me specimens of "white trap" from his collieries.

The results of an analysis of six samples of coal are tabulated below :—

TABLE I.

——	1	2	3	4	5	a	b
Moisture . .	3·80	3·27	2·22	2·22	8·22	7·85	8·59
Volatile matter .	10·11	12·40	25·08	27·43	30·43	27·95	32·92
Fixed carbon .	46·68	55·85	52·58	50·46	46·30	47·95	44·64
Ash . . .	39·41	28·48	20·12	19·90	15·05	16·25	13·86

1. Sample from contact with dyke.
2. Sample taken 3" from contact with dyke.
3. Sample taken 6" from contact with dyke.
4 Sample taken 12" from contact with dyke.
5. Mean of two analyses (a and b) of unaltered coal.
a Unaltered coal analyses by Waldie & Co., Calcutta.
b Unaltered coal.

TABLE II.

Shows the same analyses re-calculated after eliminating the water contents.

——	1	2	3	4	5	a	b
Volatile matter .	10·52	12·80	25·64	28·06	33·17	30·32	36·02
Fixed carbon .	48·52	57·74	53·77	51·60	50·43	52·03	48·83
Ash . . .	40·96	29·46	20·59	20·34	16·40	17·64	15·15

The Pench Valley coal does not coke, and little or no caking of the samples was noticed in the crucibles. Nos. 4 and b did cake slightly, but the coke formed could be powdered between the fingers.

A first glance at Table II is enough to show that there is an increase in the percentage of ash and fixed carbon, with loss of volatile matter, as the contact with the dyke is approached. The decrease of the fixed carbon at the immediate contact with the dyke is evidently due to the large amount of inorganic

[1] Analyses 1, 2, 3, 4 and b were carried out in the Geological Survey Office, Calcutta.

matter deposited in the coal by percolating water along the contact zone between the coal and the dyke.

An exactly similar set of observations was made by Sir Thomas Holland and Dr. W. Saise in connection with the peridotite dykes of the Giridih coalfield[1]. They found that (1) "there is a loss of bituminous matter as the igneous rock is approached; (2) the fixed carbon at first increases in proportion to the loss of the volatile constituents until close to the dyke the fixed carbon again decreases, which we assume to be due to its oxidation and replacement by inorganic acids; (3) the ash increases in percentage as the dyke is approached and this increase is far greater than would be due to simple removal of volatile matter."

On the same page of the above-mentioned paper the following table is given :—

TABLE III.

—	1	2	3	4
Volatile matter . . .	4·49	6·60	18·08	24·70
Fixed carbon . . .	69·50	76·24	70·89	65·99
Ash	26·01	17·16	11·03	9·31

1. Sample from contact Does not cake.
2 and 3 at a little distance from the contact. 3 cakes.
4. Unaltered coal. Cakes strongly.

Similar deductions can be drawn from C. Von Rath's[2] result in connection with an intrusive basic rock in a coal seam at Fünfkirchen in Hungary. In this set of results tabulated below, 1 is a sample of coal from the contact, 2 is a sample one foot from the contact, and 3 is a sample of unaltered coal.

TABLE IV.[3]

—	1	2	3
Volatile matter	4·70	12·20	20·30
Fixed carbon	49·34	78·07	71·41
Ash (average)	45·96	9·73	8·29

[1] *Rec. Geol. Surv. Ind.*, Vol. XXVIII, p. 133.
[2] *Neues Jahrbuch fur Min. Geol. und Pal.* Band I, pp 274--277 (1880).
[3] This table has been re-cast from that given in Von Rath's paper, p. 276.

The altered zone of the coal at Barkui is not more than 18 inches wide if so much, while the width of alteration in connection with the peridotites of the Giridih coalfield is as much as 4 feet.—

The literature treating of the thermal metamorphism of basalt dykes appears to be in consistent agreement that the effects produced by such dykes are remarkably slight. My field experience has led me to a similar opinion, except in those places where a large dolerite dyke cuts across an epidiorite or amphibolite mass. In these cases marked contact effects are observable. On pages 136-137 of their paper Sir T. H. Holland and Dr. Saise state "that the effects of contact metamorphism of the mica-peridotite are "far more striking than those of the basalts, although the latter "form very much thicker dykes. The former, we conclude, was "introduced at a very much higher temperature."

The dyke at Barkui was a doleritic basalt but is now too highly altered even to approach an ordinary fresh basalt in appearance. An examination of four specimens taken consecutively from the contact to the middle of the dyke gives the following results:—

1.B. (Rock No. 27-464; Reg. Slide No. 10133).[1]

Specimen from contact with coal.

A soft, porous, pale cream to reddish-coloured clay-like rock with a hardness of about 1·00 and a specific gravity of 2·044. On close examination it is seen to contain little nests of silvery-white crystals, so fresh looking as to suggest their being of secondary origin and probably one of the zeolite minerals which have resulted from the hydration and decomposition of porphyritic plagioclase felspars. When taken fresh in the damp state the specimens have a strong brackish taste, and when dried are distinctly clayey. To enable specimens to be cut for microscopic examination the fragments require to be baked, or heated for two days in Canada balsam.

Under the microscope the basaltic texture is quite obvious, though the component minerals are unrecognisable. The slide contains an appreciable quantity of what at first sight appear to be crosses of magnetite or ilmenite, but in reflected light show the dull white colour of leucoxene. A marked feature is the great

[1] These numbers refer to the Rock and Microscope slide Registers in the Geological Survey office, Calcutta.

development of irregularly shaped areas. These areas between crossed nicols remain dark in the middle but have a thin bright border, giving anomalous dispersion, in which the arms of the dark rotary cross are visible.

2B. (Rock No. 27-465; Slide No. 10134).

Specimen 9 inches from contact with coal.

The colour is a greenish cream to apple-green. The rock is soft and porous, and, like specimen 1B, falls to pieces readily in water. The specific gravity is over 2·00. Under the microscope it is very similar to the previous specimen. The irregular geode-like areas are not so largely developed, while leucoxene is abundant.

3B. (Rock No. 27-466; Slide No. 10135).

Specimen 12 inches from contact with coal.

This is pale green to dirty apple-green in colour, is soft but not porous, and has a specific gravity of 2·31. The outlines of lath-shaped felspars are seen; all the internal structure is, however, quite obliterated. The slide still shows the geode-like areas with spherulitic structures, while the development of leucoxene is marked.

4B. (Rock No. 27-467; Slide No. 10136).

Specimen from middle of dyke.

Dark-green in colour with a hardness of 1 to 1·5 and a specific gravity of 2·54. It has a steatitic feel and is medium to fine-grained in texture. Under the microscope the basaltic structure is distinct. The felspars have lath-shaped outlines but are too decomposed to show much more than a kind of granular anomalous dispersion between crossed nicols. No recognisable augite is to be seen, though it is suggested by occasional granulitic portions of the slide.

The dull appearance of the slide due to alteration is very prominent; nevertheless, in the confusion, beautiful contours of opaque crosses of magnetite (ilmenite) are to be seen in transmitted light. If these crosses are examined in reflected light they will be seen

to contain a delicate, dull white, skeleton cross or arrowhead of leucoxene, see figs. 2 and 3.

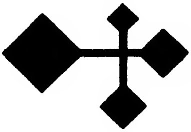

Fig. 2.—In transmitted light, magnified about 50 diameters.

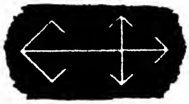

Fig. 3.—In reflected light, magnified about 50 diameters.

The amount of leucoxene, judging by its distribution in the slide, is not so abundant as in specimen 3B which contains the largest quantity. The oval and irregularly shaped geode-like areas alone show the bright border between crossed nicols. There are other circular areas, however, with a radiate, concentric, banded structure in which the whole of the rotary dark cross is seen. It is impossible to be certain from what these peculiar spherulitic patches have been derived; here, though they are in a dyke, one is inclined to regard them as the result of the alteration of shot-like inclusions which existed as glass in the unaltered dyke. Narrow dykes containing such inclusions of volcanic glass are sometimes to be found in the Chhindwara District. One such case occurs near Seoni Maigha, 8 miles north-north east of Chhindwara.

5B. (Rock No. 27-468; Slide No. 10137).

A moderately fresh specimen from a dyke in another part of the workings of the same mine. The rock is much fissured and thinly veined with calcite. The texture is that of a fine-grained basalt which is found to be very tough in excavating. Under the microscope it is also seen to be greatly altered. The laths of plagioclase felspar show no distinctive internal structure though the phenocrysts can be readily made out. The augite and interstitial matter have become a confused dirty greenish-brown matrix to the altered felspar. There are little spherulitic patches of pro-

bably original glass and large areas of decomposition products in which are seen grains of a colourless mineral having a refractive index a little lower than that of olivine, but which give dull polarization colours and oblique extinction. The grains appear so fresh that they must be regarded as secondary products of re-crystallization.

The specific gravity of these specimens varies from 2·596 to 2·630. The rock is hard and of a greyish-black colour.

With special reference to specimens 1B, 4B, and 5B,[1] the following analyses by Mr. A. K. Banerji, Assistant Curator of the Geological Survey of India, are of interest :—

TABLE V.

--	1B.	Re-cal.	4B.	Re-cal.	5B.	Re-cal.
SiO^2	40·84	44·02	33·33	37·39	36·95	40·00
TiO_3	2·68	2·90	5·57	6·33	3·05	3·27
Al_2O_3	32·13	34·80	18·97	21·15	17·88	19·25
FeO_3	2·21	2·35	7·00	7·86	5·84	6·28
FeO	1·05	1·10	9·32	10·47	12·12	13·05
MgO	0·90	0·97	3·91	4·38	5·45	5·89
CaO	2·64	2·84	1 20	1·45	3·39	3·65
K_2O	*Nil*	..	*Nil*	..	Not determined. Mn present.	
Na_2O	*Nil*	..	*Nil*	..		
H_2O (at 100°C.)	9·06	..	11·18	..	6·99	..
H_2O (above 100°C.)	10·14	11·00	9·82	10·97	6·14	6·64
TOTALS	101·65		100·30			
Sp. Gr.	2·044		2·540		2·630	

There is unfortunately no unaltered basalt in clear structural relationship with the white trap dyke. The analyses indicate a

1B. Sample from contact with coal.
4B. Sample from middle of dyke.
5B. Sample from a fresher dyke in the same mine.

nearly complete removal of the basic constituents and the marginal portions of the dyke have a composition certainly approaching that of lithomargic kaolinite. The re-calculated columns merely eliminate the moisture contents and bring up the totals to 100 for purposes of exact comparison.

Van Hise in his "Treatise on Metamorphism" appears to suggest (pages 509—516) that Al_2O_3 is an insoluble constituent of rocks, so that if equal volumes of a fresh rock and of the same rock decomposed be taken, the total weight of Al_2O_3 in each should be equal if the specimens were taken from the same rock mass. Complications will probably occur through changes of volume in a given rock as a result of decomposition and subsequent hydration.

A comparison of equal volumes of specimens 1B, 4B, and 5B, with regard to the weights of their component minerals would be roughly as follows :—

TABLE VI.

—	1B.	4B.	5B.
SiO_2	24·40	34·00	40·00
TiO_2	1·61	5·75	3·72
Al_2O_3	19·25	19·25	19·25
Fe_2O_3	1·32	7·15	6·28
FeO	0·63	9·55	13·05
MgO	0·54	3·97	5·89
CaO	1·59	1·32	3·65
Na_2O	undetermined.		..
K_2O			
H_2O (at 100°C.)	..	..	..
H_2O (above 100°C.)	6·16	10·00	6·64
	54·50	90·99	100·00

In the above table it has been assumed that specimen 5B is the freshest form of the intrusive trap that is available. It is, however, not proved that specimens 1B and 4B do actually belong to the same dyke as that from which 5B was collected, while from the microscopic examination it is known that specimen 5B is also greatly decomposed.

From Table VI it will be seen that there has been a loss of SiO_2, TiO_2, Fe_2O_3, FeO, MgO and CaO. There is an addition of CaO in specimen 1B compared with the quantity in 4B. The comparison is perhaps rather surprising and though the volume change appears to have been considerable, yet the table shows in an exaggerated form the changes that have actually taken place as the decomposition—due to the activity of carbonic acid solutions—has progressed.

These losses work out to the figures given in table VII :—

TABLE VII.

	In 1B from 4B.	In 4B from 5B.	In 1B from 5B.
	Per cent.	Per cent.	Per cent.
SiO_2	28	15	39
TiO_2	71	?	?
Fe_2O_3	81	increase	79
FeO	93	27	95
MgO	86	33	90
CaO	secondary	64	?
Alkalies	not determined.		

Van Hise[1] gives two analyses (see table VIII) of fresh basalt and also the percentage losses of the various constituents when the same rock is decomposed, and finds that the true order of loss reckoned by quantity, is lime, magnesia, soda, potash, silica and iron oxide. If this is strictly true it would appear that some of the lime

[1] *op. cit.*, p. 509.

TABLE VIII.[1]

—	Fresh Basalt.		Decomposed Basalt. Loss of each constituent.	
	1	2	1	2
			Per cent.	Per cent.
SiO_2	43·61	48·20	32·99	65·56
TiO_2	..	..	..	..
Al_2O_3	12·26	13·25	*Nil*	*Nil*
Fe_2O_3	3·51	0	50·17	88·84
FeO	12·16	16·66		
MgO	9·14	7·03	74·10	96·38
CaO	11·37	7·33	84·53	47·27
K_2O	0·81	1·81	61·69	83·34
Na_2O	2·72	2·71		74·47
Ignition	4·42	4·92	..	..
	100·00	100·00		

and magnesia of specimen 1B of the Barkui analyses is secondary, having been removed and subsequently re-deposited in the dyke rock along its contact margins with the coal.

Had a series of specimens from a perfectly fresh basalt to that of the stage of decomposition represented by specimen 1B been obtainable, a comparison of their analyses would have completely solved the problems entailed in such an alteration—an alteration whereby a hard black rock is slowly reduced to a pale cream-coloured mass having practically the composition and consistency of clay.

It is assumed[2] that the stages of alteration are: first, the formation of carbonates and the liberation of a certain amount of silica

[1] For full details of these analyses see G. P. Merrill: "Rocks, Rock-Weathering and Soils", p. 223.
[2] Teall: British Petrography, p. 46.

(probably in the colloidal, and therefore soluble, form); secondly the removal of the protoxide bases lime, magnesia and iron.

Beete Jukes[1] in a paper written in 1859 gives the following analyses of fresh basalt and of white trap from the South Staffordshire coalfield :—

TABLE IX.

—	Rowley basalt Sp. Gr. 2·907	White trap.	3
SiO_2	49·86	38·83	48·00
TiO_2	1·33	*Nil*	*Nil*
Al_2O_3	12·75	15·25	16·70
Fe_2O_3	3·30	4·335	5·40
FeO	11·38	13·83	17·30
CaO	8·71	3·925	4·80
MgO	4·395	4·180	5·26
K_2O	0·57	0·422	0·50
Na_2O	5·25	0·971	1·20
P_2O_5	0·58	*Nil*	..
CO_2	*Nil*	9·32	..
H_2O	2·56	11·01	..
	100·745	100·073	99·90

In this analysis given by Jukes the earlier phases only of the decomposition are obvious. There is a loss of SiO_2, CaO, MgO, Na_2O and K_2O, while the amount of CO_2 present in the white-trap indicates that the remaining CaO, MgO, Na_2O and K_2O have become carbonates. Column 3 of the above table is obtained by deducting the CO_2 and H_2O of the white trap both of which

[1] *Mem., Geol. Surv., Great Britain.*

constituents have been added to the fresh rock as it decomposed—and calculating the remaining constituents to 100 per cent.

Another research on white-trap was by E. Stecher.[1] His specimens were obtained from Newhalls near Queensferry. The analysis of the 'white-trap' is shown in Table X :—

TABLE X.

	"White-trap."
SiO_2	36·80
TiO_2	2·60
Al_2O_3	22·95
Fe_2O_3	?
FeO	4·08
CaO	9·73
MgO	2·85
K_2O	1·10
Na_2O	0·50
P_2O_5	0·75
CO_2	11·90
H_2O (at 100°)	6·26
H_2O (above 100°)	1·44
	100·00

Here again unfortunately no fresh basalt analysis is forthcoming, but the large amount of Al_2O_3 and the percentage of CO_2 required to form carbonates completely, may indicate a stage of alteration slightly further advanced than the South Staffordshire white trap of Jukes. In comparison, the white trap of Barkui would appear to have finally, at least along its margins, ended as clay and so is a veritable clay-dyke which, according to Ladds'[2] classification, would probably be classed as indigenous clay occurring in veins.

The dyke is so fissured that the leaching out of the soluble constituents must be rapidly taking place, while from the analyses it would seem that the TiO_2 is first liberated from the ilmenite and then dissolved but with more difficulty than either the Fe_2O_3 Or FeO.

[1] *Proc., Roy. Soc., Edin.*, Vol. XV, p. 172, 1888.
[2] Clays, Henri Reis., p. 24 (1906).

In the Bengal coalfields it is well-known that two distinct sets of intrusive basic rocks occur [1] (1) the mica-peridotites [2] which "are younger than the Raniganj Series and older than the Rajmahal traps" and (2) large dykes of basalt which are "probably the underground representatives of the Rajmahal lava flows."

A similar distribution of basic dykes has not yet been possible for the Satpura coalfields. There are abundant dykes which cut through the Gondwana rocks, but so far as observation goes they are all dolerites and basalts of the Deccan Trap period. In the first survey of the Narbada valley it was thought that there were two sets of intrusions in the strata [3] but a re-consideration [4] led to the conclusion that the dykes were all of one period - that of the Deccan Trap. E. J. Jones in his re-survey of the Satpura coalfield does not differentiate the trap dykes into two series, but he brings forward more evidence for regarding the dykes as of Deccan Trap age [5]. From these considerations it is fair to conclude that the dykes in the workings of Barkui colliery belong to the Deccan Trap period of eruptions.

Owing to its faulted character it was at first considered that the Barkui dyke was not likely to be of Deccan Trap age, since the basalt dykes of the Bengal coalfields are newer than the faults of those coalfields. This, however, is now no difficulty; for, since then, sufficient evidence has recently come to hand to prove that the Deccan Trap lavas of the Chhindwara district have been disturbed by earth-movements, [6] and in the Linga area, immediately south of Chhindwara, they have been folded into gentle anticlines and synclines, and in places distinctly faulted. A large dolerite dyke (10 yards wide) of Deccan Trap age, which can be followed almost continuously for 40 miles, is clearly faulted near the village of Belgaon on the Bel River in the Chhindwara district. The horizontal displacement of the faulted limb of this dyke is quite 75 to 100 yards. The western limb has been moved to the south while the portion to the east has been pushed to the north, the trend of the dyke being practically due east and west.

[1] *Rec., Geol. Surv. Ind.*, Vol. XXVIII, pt. 4, p. 126.
[2] *Rec., Geol. Surv. Ind.*, Vol. XXXVII, pt. 4, p. 141.
[3] *Mem., Geol. Surv. Ind.*, Vol. II, p. 217, 1860.
[4] *Mem., Geol. Surv. Ind.*, Vol. X. Art. 2, p. 47.
[5] *Mem., Geol. Surv. Ind.*, Vol. XXIV, p 57, 1891.
[6] *Rec., Geol. Surv. Ind.*, Vol. XLII, pt. 2, pp. 89-90

In conclusion I would record my indebtedness to Mr. A. H. Parry for his kindness in selecting and forwarding the specimens of coal and trap from Barkui colliery and to my colleagues Mr. G. H. Tipper and Dr. W. A. K. Christie for their advice on various occasions.

STATEMENT OF MINERAL CONCESSIONS GRANTED DURING 1913.

ASSAM.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Cachar . .	(1) Mr. W. Gordon Stoker	Oil	P. L. .	3,180·8	12th April 1913.	1 year.
Do. .	(2) Mr. H. Weir . .	Do.	P. L. .	6,419·2	26th May 1913.	Do.
Khasi and Jaintia Hills.	(3) Mr. R. D. Coggan .	Gold, tin and certain other allied minerals.	P. L. .	12,704	14th March 1913.	Do.
Do. .	(4) Do. .	Do. .	P. L. .	8,160	14th March 1913.	Do.
Do. .	(5) Messrs. Turner, Morrison & Co.	Red ochre, yellow ochre, cinnabar, barytes and gypsum.	P. L. .	672	11th April 1913.	Do.
Do. .	(6) Mr. J. O. Shoobridge	Mercury . .	P. L. .	568	30th April 1913.	Do.
Do. .	(7) Mr. R. H. Henderson	Coal	P. L. .	4,131·84	7th July 1913	Do.
Sylhet . .	(8) Messrs. Kilburn & Co.	Oil	P. L. .	6,400	4th January 1913.	Do.
Do. . .	(9) Mr. G. M. Prichard .	Petroleum . .	P. L. .	9,600	20th February 1913.	Do.

BALUCHISTAN.

Sibi . .	(10) Khan Bahadur B. D. Patel, C.I.E.	Coal .	M. L. .	225	1st January 1913.	30 years.
Do. . .	(11) Mr. W. C. Clements of Sharigh.	Do. .	M. L. .	80	1st July 1913	Do.
Do. . .	(12) Khan Bahadur B. D. Patel, C.I.E.	Do. . .	M. L. .	80	1st January 1913.	Do.
Zhob . .	(13) Khan Bahadur B. D. Patel, C.I.E.	Chromite . .	M. L.	80	1st July 1913	Do.
Do. . .	(14) The Baluchistan Mining Syndicate.	Do. . .	M. L.	2,740	1st January 1914.	Do.

BENGAL.

Chittagong .	(15) Mr. A. M. Barkely	Mineral oil . .	P. L. .	2,160	28th March 1912.	1 year.
Do. .	(16) Messrs. Turner, Morrison & Co.	Do. . .	P. L. .	1,934	22nd June 1912.	Do.
Do. .	(17) Messrs. Burma Oil Co.	Do. . .	P. L. .	4,000	16th April 1913.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BENGAL—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chittagong .	(18) Messrs. Turner, Morrison & Co.	Mineral oil . .	P. L. .	1,934	22nd June 1913.	1 year.
Darjeeling .	(19) Mr. P. N. Bose .	Coal . . .	M. L. .	158 (more or less)	1st January 1913.	20 years.

BIHAR AND ORISSA.

Hazaribagh .	(20) Mr. C. A. Dickson .	Mica . . .	P. L. .	257	18th April 1913.	1 year.
Do. .	(21) Mr. W. Snell . .	Do. . . .	P. L. .	147·60	9th June 1913.	Do.
Do. .	(22) Babu Akhoy Kumar Gupta.	Do. . . .	M. L. .	21·61	27th September 1912.	30 years.
Do. .	(23) Mr. Archibald A. C. Dickson.	Do. . . .	P. L. .	80	26th June 1913.	1 year.
Do. .	(24) Mr. E. O. R. Myers	Do. . . .	P. L. .	40	4th July 1913.	Do.
Do. .	(25) Babu Raghubir Rai	Do. . . .	P. L. .	40	27th July 1913.	Do.
Do. .	(26) Mr. G. B. Knowles .	Do. . . .	P. L. .	200	1st September 1913.	Do.
Do. .	(27) Babu Shivji Walji .	Do. . . .	P. L. .	80	10th September 1913.	Do.
Do. .	(28) Babu Lachmi Narain Shroff.	Do. . . .	P. L. .	126	15th September 1913.	Do.
Do. .	(29) Babu Lakshmi Narayan Sukhani.	Do. . . .	P. L. .	40	12th October 1913.	Do.
Do. .	(30) Babu Hari Narain Singh.	Do. . . .	P. L. .	60	8th November 1913.	Do.
Do. .	(31) Babu Baidya Nath Saha.	Do. . . .	M. L. .	160	22nd March 1913.	30 years.
Do. .	(32) Babu Satyendra Pada Sarkar.	Do. . . .	M. L. .	154·0	23rd August 1913.	Do.
Do. .	(33) Babu Santosh Kumar Majumdar.	Do. . . .	M. L. .	274	30th September 1913.	Do.
Puri . .	(34) Miss Florentia W. Harrison, M.D., of Waltair.	Oxide of iron .	M. L. .	160	1st November 1912.	Do.
Santhal Parganas.	(35) Babu Binode Bihari De.	Coal . . .	M. L. .	3·75	1st December 1912.	3 years.
Do. .	(36) Babu Ramani Kanta De.	Do. . . .	M. L. .	5·5	1st December 1912.	Do.
Do. .	(37) Babu Binode Bihari De.	Do. . . .	M. L.	1·5	1st March 1913.	Do.

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BIHAR AND ORISSA—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Santhal Parganas.	(38) Babu Sashi Bhusan De.	Coal	M. L.	1	1st March 1913.	3 years.
Do.	(39) Babu Baidya Nath De.	Do.	M. L.	About 35·2 acres.	1st August 1913.	Do.
Singhbhum	(40) Messrs. Schröder, Smidt & Co., Ltd., of Calcutta.	Manganese	P. L. (renewal).	1,472	15th January 1913.	1 year.
Do.	(41) Do.	Chromite	P. L. (renewal).	About 3,891·2 acres.	12th June 1913.	Do.
Do.	(42) Rai Srinath Pal Bahadur of Calcutta.	Manganese	P. L. (renewal).	About 400 acres.	9th August 1913.	Do.

BOMBAY.

Ratnagiri	(43) Messrs. Jambon & Cie. of Calcutta.	Chromium and iron.	P. L.	727	12th June 1913.	1 year.

BURMA.

Akyab	(44) Mr. J. M. J. Goodman.	Mineral oil	P. L. (renewal).	2,560	17th May 1912.	Up to 23rd November 1913.
Do.	(45) Do.	Do.	E. L. (renewal).	12,793·6	26th August 1912.	1 year.
Do.	(46) Do.	Do.	E. L. (renewal).	9,984	23rd November 1912.	Do.
Do.	(47) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do.	P. L.	5,440	19th June 1913.	Do.
Do.	(48) Do.	Do.	P. L.	5,760	8th October 1913.	Do.
Do.	(49) Do.	Do.	P. L.	1,031·09	15th December 1913.	Do.
Amherst	(50) Mr. R. E. Smith	All minerals (except mineral oil).	P. L.	1,920	9th January 1913.	Do
Do.	(51) Do.	Tin, wolfram and other minerals (except oil).	P. L.	1,440	19th January 1913.	Do.
Do.	(52) Do.	Do.	P. L.	1,920	11th March 1913.	Do.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Amherst .	(53) Mr. L. Sisman .	All minerals (except mineral oil).	P. L. .	640	10th June 1913.	1 year.
Do. .	(54) Maung Po . .	Do. .	P. L. .	3,200	11th August 1913.	Do.
Do. .	(55) Mrs. M. M. Hla-Oung.	Do. .	P. L. .	2,880	28th July 1913.	Do.
Do. .	(56) Messrs. T. D'Castro & Son.	Do. .	P. L. .	320	9th December 1913.	Do.
Do. .	(57) Mr. C. E. Law .	Gold, silver, tin, copper, wolfram and antimony.	P. L. .	7,680	8th November 1913.	Do.
Do. .	(58) Messrs. T. D'Castro & Son.	All minerals (except mineral oil).	P. L. (renewal).	1,280	4th October 1913.	Do.
Do. .	(59) Ma Saw Nyun .	Do. .	P. L. (renewal).	1,280	30th October 1913.	Do.
Katha . .	(60) Moolla Dawood .	Gold, silver, lead, copper and mica.	P. L. (renewal).	640	19th February 1913.	Do.
Do. . .	(61) C. Soon Thin .	Galena or lead .	P. L. (renewal).	2,464	17th March 1913.	Up to 31st August 1913.
Do. . .	(62) The Hon'ble Mr. Lim Chin Tsong and Mr. J. A. Manyon.	Copper and copper-ore.	M. L. .	2,880	1st January 1912.	30 years.
Do. . .	(63) Maung Nyo . .	Lead and silver .	P. L. (renewal).	960	2nd May 1913	Up to 31st December 1913.
Do. . .	(64) Maung Tun Man .	Gold, silver, copper, tin and lead.	P. L. (renewal).	751·36	12th April 1913.	1 year.
Kyaukpyu .	(65) Maung Charley .	Mineral oil . .	P. L. .	639·69	1st March 1913.	Do.
Do. .	(66) Mr. McCarren .	Do. . .	P. L. .	344·52	15th October 1913.	Do.
Kyaukse .	(67) Saw Lein Lee .	All minerals (except mineral oil).	P. L. .	1,800·16	13th November 1913.	Do.
Lower Chindwin.	(68) Messrs. The Burma Oil Co., Ltd.	Mineral oil . .	P. L. .	960	1st May 1913	Do.
Do. .	(69) Maung Thin . .	Gold, silver, iron and lead.	P. L. .	364·8	1st June 1913.	Do.
Do. .	(70) Mohamed Hoosein .	All minerals (except mineral oil).	P. L. .	1,440	1st August 1913.	Do.
Do. .	(71) Maung Thin .	Iron-ore . .	P. L. .	54·30	1st September 1913.	Do.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Magwe . .	(72) Messrs. The Indo-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. .	1,280	5th June 1913.	1 year.
Do. . .	(73) Messrs. The Burma Oil Co., Ltd.	Do. . .	M. L. (renewal).	30·55 acres, 164 state wells in the Twingon and Beme Reserves and known as the Yenangyaung state well Holdings.	1st January 1913.	30 years.
Meiktila .	(74) Mr. A. R. Finlay .	Wolfram . .	P. L. .	1,920	4th March 1913.	1 year.
Do. .	(75) Maung San . .	Do. .	P. L. .	2,560	21st February 1913.	Do.
Mergui . .	(76) Mrs. B. I. Jewett .	All minerals (except mineral oil).	P. L. .	3,200	13th February 1913.	Do.
Do. . .	(77) Maung Po Gyi and Maung Shan Byu.	Do. .	P. L. .	3,150·04	11th January 1913.	Do.
Do. . .	(78) Mr. J. Kinloch .	Do. .	P. L. .	1,039·36	26th March 1913.	Do.
Do. . .	(79) Purshotumrao A. Patker.	Do. .	E. L. .	Mergui District.	13th March 1912.	Do.
Do. . .	(80) Mr. A. E. Landon White.	Coal . . .	P. L. .	2,362·88	29th March 1913.	Do.
Do. . .	(81) Sit Kwet . .	All minerals (except mineral oil).	P. L. (renewal).	1,088·98	2nd September 1912.	Do.
Do. . .	(82) Maung Kya Bin .	Do. .	P. L. (renewal).	3,200	14th September 1912.	Do.
Do. . .	(83) Maung Shwe Thi .	Do. .	P. L. (renewal).	852·48	5th October 1912.	Do.
Do. . .	(84) Do. .	Do. .	P. L. (renewal).	81·60	2nd October 1912.	Do.
Do. . .	(85) Maung Kyaw .	Do. .	P. L. (renewal).	2,151·40	15th November 1912.	Do.
Do. . .	(86) Do. .	Do. .	P. L. (renewal).	1,041·92	20th November 1912.	Do.
Do. . .	(87) Maung Shwe Yeik .	Do. .	P. L. (renewal).	714·56	21st December 1912.	Do.
Do. . .	(88) Do. .	Do. .	P. L. (renewal).	2,304	21st December 1912.	Do.
Do. . .	(89) Maung Po Gyi .	Do. .	P. L. (renewal).	2,124·80	1st January 1913.	Do.
Do. . .	(90) Maung Shwe Yeik .	Do. .	P. L. (renewal).	3,200	21st February 1913.	Do.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui . .	(91) Maung Saw Maung.	All minerals (except mineral oil).	P. L. .	430·30	10th May 1913	1 year.
Do. . .	(92) Messrs. Bume and Reif.	Tin	P. L. .	2,396·16	5th June 1913	Do.
Do. . .	(93) Messrs. The Burma Oil Co., Ltd.	Mineral oil . .	P. L. .	2,240	19th February 1913.	Do.
Do. . .	(94) Maung Kyin Ton .	All minerals (except mineral oil).	P. L. .	1,600	19th January 1913.	Do.
Do. . .	(95) Mr. G. H. Hand .	Do. .	P. L. .	1,991·96	8th May 1913	Do.
Do. . .	(96) Maung Kya Sin .	Do. .	P. L. .	3,200	27th June 1913.	Do.
Do. . .	(97) Gowri Shanker Alwcshar.	Do. .	P. L. .	2,942·12	26th June 1913.	Do.
Do. . .	(98) Saw Leng Lee	Do. .	P. L. (renewal).	660·48	2nd September 1912.	Do.
Do. . .	(99) Maung Shwe Yeik .	Do. .	P. L. (renewal).	714·56	21st December 1912.	Do.
Do. .	(100) Do. .	Do. .	P. L. (renewal).	2,304	21st December 1912.	Do.
Do. . .	(101) Messrs. Bume and Reif.	Do. .	P. L. (renewal).	2,755·04	10th November 1912.	Do.
Do. . .	(102) Do. .	Do. .	P. L. (renewal).	1,064·91	Do. .	Do.
Do. . .	(103) Do. .	Do. .	P. L. (renewal).	1,617·92	Do. .	Do.
Do. . .	(104) Do. .	Do. .	P. L. (renewal).	1,661	Do. .	Do.
Do. . .	(105) Do. .	Do. .	P. L. (renewal).	1,528·08	Do. .	Do.
Do. . .	(106) Do. .	Do. .	P. L. (renewal).	619·52	Do. .	Do.
Do. . .	(107) Do. .	Do. .	P. L. (renewal).	547·84	29th January 1913.	Do.
Do. . .	(108) Do. .	Do. .	P. L. (renewal).	2,862·80	29th January 1913.	Do.
Do. . .	(109) U. Shwe I . .	Do. .	P. L. (renewal).	1,478·88	2nd February 1913.	Do.
Do. . .	(110) Maung Po Thaik .	Do. .	P. L. (renewal).	814·08	21st March 1913.	Do.
Do. . .	(111) Do. .	Do. .	P. L. (renewal).	1,766·40	Do. .	Do.
Do. . .	(112) Maung Thein Pe .	Do. .	P. L. .	1,600	11th August 1913.	Do.
Do. . .	(113) Maung Kya Sin .	Do. .	P. L. .	3,069·28	15th September 1913.	Do.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui . .	(114) Moolla Dawood Sons & Co.	All minerals (except mineral oil).	P. L. .	3,200	24th September 1913.	1 year.
Do. . .	(115) Do. .	Do. .	P. L. .	3,200	24th September 1913.	Do.
Do. . .	(116) Maung Po Ghine .	Do. .	P. L. (renewal).	2,088·96	21st May 1913	7 months.
Do. . .	(117) Maung Thein Pe .	Do. .	P. L. (renewal).	199·68	31st May 1913	1 year.
Do. . .	(118) U. Shwe I . .	Do. .	P. L. (renewal).	3,200	7th June 1913	Do.
Do. . .	(119) E Ahmed . .	Do. .	P. L. (renewal).	2,898·56	28th July 1913	Do.
Do. . .	(120) Saw Leng Lee .	Do. .	P. L. (renewal).	660·48	2nd September 1913.	Do.
Do. . .	(121) Musaji . . .	Do. .	E. L. .	Mergui District.	2nd February 1913.	Do.
Do. . .	(122) Mr. A B Snow .	Do. .	P. L. .	3,200	18th November 1913.	Do.
Do. . .	(123) Messrs. Moolla Dawood Sons & Co.	Do. .	P L .	3,011 04	15th November 1913.	Do.
Do . .	(124) Maung Ne Gyi .	Do. .	P. L. .	2,700·80	8th October 1913.	Do.
Do. . .	(125) E Ahmed . .	Do. .	P. L. .	1,318·56	30th November 1913.	Do.
Do. . .	(126) Do. . .	Do. .	P. L. .	2,316·80	30th October 1913.	Do.
Do. . .	(127) G. Shwe Yin .	Do. .	E. L. .	Mergui District.	25th October 1913.	Do.
Do. . .	(128) Eng Sit Yan .	Do .	P. L. .	1,172·48	6th December 1913.	Do.
Do. . .	(129) Maung Mya .	Do. .	P. L. (renewal).	1,809·92	16th February 1913.	Do.
Do. . .	(130) Sit Shu . .	Do. .	P. L. (renewal).	1,369·44	1st September 1913.	Do.
Do. . .	(131) Messrs. Wrightman & Co.	Do. .	P. L. (renewal).	3,200	14th September 1913.	Do.
Do. . .	(132) Messrs. Bume and Relf.	Do. .	P. L. (renewal).	2,775·04	11th November 1913.	Do.
Do. . .	(133) Do. .	Do. .	P. L. (renewal).	2,396·16	5th June 1914	Do.
Do. . .	(134) Do. .	Do. .	P. L. (renewal).	1,528·08	11th November 1913.	Do.
Do. . .	(135) Do. .	Do. .	P. L. (renewal).	701·77	Do. .	Do.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui . .	(136) Messrs. Bume and Biof.	All [minerals (except mineral oil).	P. L. (renewal).	1,510·40	10th November 1913.	1 year.
Minbu . .	(137) Messrs. The Burma Oil Co., Ltd.	Mineral oil . .	M. L. .	1,600 (Block 2-N., western halves of 4-S. and 6-S. and eastern half of 5-S.).	1st January 1911.	30 years.
Do. . .	(138) Tar Mahomed Ismail.	Do . .	P. L. .	821·76 (western half of Block 1-N., eastern half of Block 10-S. and Block 12-S.).	28th January 1913.	1 year.
Do . .	(139) Maung Taik Gyi and Maung Shwe Mo.	Do. . .	P. L. .	27·09	28th January 1913.	Do.
Do. . .	(140) Maung Pan U and three others	Do. . .	P. L. .	960 (Block 7-P. and southern half of Block 3-P.).	28th November 1912.	Do.
Do. . .	(141) Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. .	320 (Northern half of Block 16-N.).	28th January 1913.	Do.
Do. . .	(142) Maung Pan U and three others.	Do. . .	P. L. .	320	5th October 1912.	Do.
Do. . .	(143) Abdul Karim Suleman.	Do. . .	P. L. .	960 (eastern half of Block 1-N., western half of Block 5-S., and Block 9-S.).	4th February 1913.	Do.
Do. . .	(144) Maung Kin . .	Do. . .	P. L. .	320 (western half of Block 11-N.).	22nd January 1913.	Do.
Do. . .	(145) Maung Mo Gaung	Do. . .	P. L. .	1,280 (undemarcated Block 5-R. and western halves of Blocks 3-N. and 4-N.).	23rd October 1912.	Do.
Do. . .	(146) Messrs. The British Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	614·40	3rd January 1913.	Do.
Do. . .	(147) Captain H. Fenton	Do. . .	P. L. (renewal).	2,560	27th August 1912.	Do.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Minbu . .	(148) Messrs. The Burma Oil Co., Ltd.	Mineral oil .	M. L. .	2,683 (western half of Block 8-S., eastern halves of Blocks 7-S. 9-S., 11-S., 13-S. 15-S., and 17-S., and a portion of Block 2-S., in the Minbu oil-field).	1st April 1911	30 years.
Do. . .	(149) Irrawaddy Petroleum Oil Syndicate, Ltd.	Do. . .	M. L. .	960 (Block A-S. and western half of Block 17-S.).	1st October 1911.	Do.
Do. . .	(150) Maung Myat Kaung and Jhande Khan.	Do. . .	P. L. .	308 (eastern half of Block 17-R.).	17th March 1913.	1 year.
Do. . .	(151) Maung Tun Aung Gyaw.	Do. . .	P. L. (renewal).	1,290·54 (Blocks 14-P., 15-P., and northern portion of Block 16-P. in the Minbu oil-field).	28th February 1913.	Do.
Do. . .	(152) The Irrawaddy Petroleum Oil Syndicate, Ltd.	Do. . .	M. L. .	320 (western half of Block 18-S., of the Minbu oil-field).	6th February 1912.	30 years.
Do. . .	(153) Maung Tha Han and Maung So Thein.	Do. . .	P. L. .	640 (eastern halves of Blocks 1-S. and 8-N. in the Minbu oil-field).	5th May 1913	1 year.
Do. . .	(154) Ma Saw Ya . .	Do. . .	P. L. .	320 (eastern half of Block 9-N. in the Minbu oil-field).	5th July 1913	Do.
Do. . .	(155) Salin Oil Co., Ltd.	Do. . .	M. L. .	594·00	1st May 1912	30 years.
Do. . .	(156) Messrs. The Burma Oil Co., Ltd.	Do. . .	M. L. .	960·00 (the eastern half of Block 18-S. and undemarcated Block F-S. in the Minbu oil-field).	1st May 1912	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Minbu . .	(157) Maung Taik Gyi and Maung Shwe Mo.	Mineral oil . .	M. L. .	320 (the western half of Block 16-S. in the Minbu oil-field).	1st March 1913.	30 years.
Do. . .	(158) Mr. P. Samuel .	Do. . .	P. L. .	640 (western halves of Blocks 1-S. and 7-S. in the Minbu oil-field).	10th October 1913.	1 year.
Myingyan .	(159) The British Burma Petroleum Co., Ltd.	Do. . .	M. L. .	640 (Block 54-N. of the Singu oil-field).	30th October 1911.	30 years.
Do. .	(160) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. (renewal).	1,280	15th September 1912.	1 year.
Do. .	(161) Mr. L. A. Maing .	Do. . .	P. L. (renewal).	640	25th September 1912.	Do.
Do. .	(162) Messrs. The Moolla Oil Co., Ltd.	Do. . .	M. L. .	1,280	13th August 1912.	30 years.
Do. .	(163) Maung Tun Aung Gyaw.	Do. . .	P. L. .	208·10	4th September 1913.	1 year.
Do. .	(164) Messrs. I. M. Mamsa & Co.	Do. . .	P. L. .	320	28th October 1913.	Do.
Do. .	(165) Do. .	Do. . .	P. L. .	640 (Block 50-N. in the Singu oil-field).	16th December 1913.	Do.
Do. .	(166) Messrs. Shwe Oh Bros. & Co.	Do. .	P. L. (renewal).	800	3rd January 1913.	Do.
Do. .	(167) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	425·60	10th July 1913	Do.
Do. .	(168) Messrs. The British Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	640 (Block 52-N. in the Singu oil-field).	12th July 1913.	Do.
Do. .	(169) Mr. L. A. Maing .	Do. . .	P. L. (renewal).	640 (Block 24-N. in the Singu oil-field).	25th September 1913.	Do.
Myitkyina .	(170) Mr. W. H. Halley	Gold . . .	P. L. .	1,280	1st August 1913.	Do.
Do. .	(171) Mr. B. A. Baldwin	Gold, platinum and allied minerals.	P. L. .	1,440	9th October 1913.	Do.
Do. .	(172) Do. .	Platinum .	P. L. (renewal).	3,360	28th October 1913.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Northern Shan States.	(173) Mr. W. R. Hillier	Coal . . .	P. L. .	1,920	21st February 1913.	1 year.
Do. .	(174) Mr. G. Adams .	Do. . .	P. L. .	640	20th June 1913	Do.
Do. .	(175) Saw Hke, Sawbwa of Hsipaw.	All minerals (except mineral oil).	E. L. .	The whole of Hsipaw State except such parts as are included in Forest Reserves.	12th June 1913	Do.
Do. .	(176) Mr. J. Shepherd .	Coal . . .	P. L. (renewal).	640	7th August 1913.	Do.
Do. .	(177) Mr. W. R. Hillier .	Copper and allied metals	P. L. (renewal).	2,560	10th July 1913	Do.
Pakokku .	(178) Li Kan Shoo .	Mineral oil . .	P. L. .	6,400	14th February 1913.	Do.
Do. .	(179) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	744·96	8th March 1913.	Do.
Do. .	(180) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. .	2,560	22nd July 1913.	Do.
Do. .	(181) Messrs. The Moolla Oil Co., Ltd.	Do. .	P. L. (renewal).	1,520	4th March 1913.	Do.
Do. .	(182) Maung Aung Gyi, Maung Kyaw Nyun and Maung Ya Hml.	Do. . .	M. L. .	1,280	22nd March 1912.	30 years.
Do. .	(183) Maung Po Thaik and Maung Ya da.	Do. . .	P. L. .	9,534·01	8th December 1913.	1 year.
Do. .	(184) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. (renewal).	351·65 (Block D-2 of the Yenangyat oil-field).	25th July 1913.	Do.
Prome . .	(185) Maung Shwe Hlaing.	Do. . .	P. L. .	499·2	20th January 1913.	Do.
Do. . .	(186) Maung Po O and Maung Po Tôk	Do. . .	P. L. .	2,924·8	7th March 1913.	Do.
Do. . .	(187) Maung Gyi . .	Do. . .	P. L. .	1,862·4	5th March 1913.	Do.
Do. . .	(188) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. .	3,200	31st May 1913	Do.
Do. . .	(189) Maung Pe . .	Do. . .	M. L. .	123·40	9th May 1912	30 years.
Sagaing .	(190) C. Soon Thin .	Do. . .	P. L. .	1,920	13th January 1913.	1 year.
Do. .	(191) Do. .	Do. . .	P. L. (renewal).	3,190	30th July 1913.	Do.
Shwebo .	(192) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	1,280	24th May 1913.	Do.

E. L.=*Exploring License.* P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Shwebo .	(193) Messrs. The Indo-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. (renewal).	5,120	19th September 1913.	1 year.
Do. . .	(194) Do. .	Do. . .	P. L. (renewal).	5,120	19th September 1913.	Do.
Southern Shan States.	(195) Maung Maung .	All minerals (except mineral oil).	P. L. .	3,200	5th March 1913.	Do.
Do. .	(196) Lt.-Col. G. Rippon.	Tungsten, tin, copper and associated minerals.	P. L. (renewal).	2,560	4th January 1913.	Do.
Do. .	(197) Mr. John Terndrup	Gold, copper, tin, galena, wolfram and tungsten.	P. L. .	3,200	13th April 1913.	Do.
Do. .	(198) Messrs. J. A. Begbie & Co.	All minerals (except mineral oil).	P. L. .	3,200	25th June 1913.	Do.
Do. .	(199) Dowalachi Galena Syndicate.	Lead, copper and silver.	P. L. .	3,200	3rd May 1913	Do.
Do. .	(200) Do. .	Coal . .	P. L. .	7,360	21st June 1913.	Do.
Do. .	(201) Mr. L. P. Doclozets	All minerals (except mineral oil).	P. L. .	1,440	13th June 1913.	Do.
Do. .	(202) Messrs. J. A. Begbie & Co.	Do. .	P. L. .	3,162	22nd September 1913.	Do.
Do. .	(203) Htamong Ye .	Lead and silver .	M. L. .	7·38	1st June 1913	5 years.
Do. .	(204) Mr. John Terndrup	Wolfram tungsten, copper, tin, galena and gold.	P. L. .	2,720	10th July 1913.	1 year.
Do. .	(205) Messrs. The Southern Shan States Syndicate (1909), Ltd.	Gold and associated minerals.	P. L. .	2,240	22nd September 1913.	Do.
Do. .	(206) Do. .	Do. .	P. L. .	3,200	22nd September 1913.	Do.
Do. .	(207) Do. .	Do. .	P. L. .	2,347	1st August 1913.	Do.
Do. .	(208) Messrs. J. A. Begbie & Co.	All minerals (except mineral oil).	P. L. .	384	22nd September 1913.	Do.
Do. .	(209) Maung Yaing .	Silver and lead	P. L. (renewal).	400	20th July 1913.	Do.
Do. .	(210) Lt.-Col. G. Rippon	Copper, gold, silver and associated minerals.	P. L. .	1,120	28th October 1913.	Do.
Do. .	(211) Mr. O. H. DePaulsen.	All minerals (except mineral oil).	P. L. .	800	29th November 1913.	Do.
Do .	(212) Hon'ble Mr. Lim Chin Tsong.	Do. .	P. L. .	2,120	27th October 1913.	Do.
Tavoy . .	(213) Sulaiman Adamjee	All minerals (except mineral oil).	P. L. .	3,200	24th February 1913.	Do.

E. L.—*Exploring License.* P. L.—*Prospecting License.* M. L.—*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy . .	(214) Ma Dwe . .	All minerals (except mineral oil).	P. L. (renewal).	2,446·08	13th June 1912.	1 year.
Do. . .	(215) Tan Shwe Cho .	Do. .	P. L. (renewal).	1,835·35	1st November 1912.	Do.
Do. . .	(216) The Burma-Malaya Mines, Ltd.	Do. .	P. L. (renewal).	6,250	31st December 1912.	3 months from 31st December 1912.
Do. . .	(217) Mr. G. E. Elburn .	Do. .	P. L.	2,755	23rd June 1913.	1 year.
Do. . .	(218) E. Zin Bros. & Co.	Do. .	P. L.	1,000	6th June 1913	Do.
Do. . .	(219) Moola Golam Mahomed.	Do. .	P. L.	2,320	23rd June 1913.	Do.
Do. . .	(220) Tavoy Concessions, Ltd.	Do. .	P. L. (renewal).	691·20	3rd July 1912	Do.
Do. . .	(221) Khoo Tun Byan .	Do. .	P. L. (renewal).	2,615	20th August 1912.	Do.
Do. . .	(222) Rangoon Mining Co.	Do. .	P. L. (renewal).	3,200	26th September 1912.	Do.
Do. . .	(223) Egani Tavoy Mining Co.	Do.	P. L. (renewal).	2,430	2nd December 1912.	Do.
Do. . .	(224) Mr. P. P. Murphy	Do.	P. L.	690	24th July 1913.	Do.
Do. . .	(225) Maung Lu Pe .	Do. .	P. L.	712	21st July 1913.	Do.
Do. . .	(226) Mr. W. S. Wood .	Do. .	P. L.	2,240	7th August 1913.	Do.
Do. . .	(227) Mr. J. F. Studdert	Do. .	P. L.	810	8th July 1913	Do.
Do. . .	(228) Tsong Shwe Sin .	Do. .	P. L.	2,462	18th August 1913.	Do.
Do. . .	(229) Khoo Zun Nee .	Do. .	P. L.	794	29th August 1913.	Do.
Do. . .	(230) Messrs. The Burma Rice and Trading Co.	Do. .	P. L.	2,990	16th July 1913.	Do.
Do. . .	(231) Mr. G. R. Gilfillan	Gold and tin .	P. L.	2,172·52	25th November 1912.	Do.
Do. . .	(232) The Leibaoak Syndicate.	All minerals (except mineral oil).	P. L.	963	24th September 1913.	Do.
Do. . .	(233) Do. .	Do. .	P. L.	2,371	7th August 1913.	Do.
Do. . .	(234) Quah Chong Gwan	Do. .	P. L.	490	23rd August 1913.	Do.
Do. . .	(235) Messrs. Ung Kyee Pe Bros. & Co.	Do. .	P. L.	279	15th September 1913.	Do.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy . .	(236) The Rangoon Mining Co.	All minerals (except mineral oil).	P. L. (renewal).	2,881	22nd July 1912.	1 year.
Do. . .	(237) Lim Kyee Yan .	Do. .	P. L. (renewal).	1,420·80	9th August 1912.	Do.
Do. . .	(238) Ma Thaw . .	Do. .	P. L. (renewal).	1,228	21st July 1913.	Do.
Do. . .	(239) Messrs. The Tavoy Concessions, Ltd.	Do. .	P. L. (renewal).	1,434	30th August 1912.	Do.
Do. . .	(240) Do. .	Do. .	P. L. (renewal).	2,086	9th September 1912.	Do.
Do. . .	(241) Messrs. The Burma-Malaya Mines, Ltd.	Do. .	P. L. (renewal).	2,400	2nd January 1913.	Do.
Do. . .	(242) Khoo Jin Teik .	Do. .	P. L. (renewal).	3,200	13th August 1913.	Do.
Do. . .	(243) Messrs. The Tenasserim Concessions, Ltd.	Do. .	P. L. (renewal).	1,011·2	1st March 1913.	Do.
Do. . .	(244) Maung E. Cho .	Do .	P. L. (renewal).	2,668	2nd February 1913.	Do.
Do. . .	(245) Ma Sein Daing .	Do. .	P. L. (renewal).	445	2nd February 1913.	Do.
Do. . .	(246) Mr. T. Fowle .	Do. .	P. L. (renewal).	4,478	10th February 1913.	Do.
Do. . .	(247) Maung Tun Mya .	Do. .	P. L. (renewal).	813·2	10th April 1913.	Do.
Do. . .	(248) Maung E Cho .	Do. .	P. L. (renewal).	709	12th April 1913.	Do.
Do. . .	(249) M. Lubbai Saib .	Do. .	P. L (renewal).	1,280	10th April 1913.	Do.
Do. . .	(250) Hermingyi Mining Co.	Do.	P. L. (renewal).	2,099	24th December 1912.	Do.
Do. . .	(251) Messrs. The Tavoy Concessions, Ltd.	Do.	P. L. (renewal).	692	3rd July 1913.	Do.
Do. . .	(252) Rangoon Mining Co., Ltd.	Do. .	P. L. (renewal).	2,880	14th August 1913.	Do.
Do. . .	(253) Messrs. The Hindu Chaung Tin Dredging and Mining Co.	Gold, tin and wolfram.	M. L. .	294·8	21st July 1912.	30 years.
Do. . .	(254) Maung E Cho .	All minerals (except mineral oil).	P. L. .	2,320	24th November 1913.	1 year.
Do. . .	(255) Ong Hoe Kyin .	Do. .	P. L. .	258	5th November 1913.	Do.
Do. . .	(256) Mr. S. Crawshaw .	Do. .	P. L. .	720	11th December 1913.	Do.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy . .	(257) Messrs. The Burma Rice and Trading Co., Ltd.	All minerals (except mineral oil).	P. L .	3,134	8th November 1913.	1 year.
Do. . .	(258) Messrs. The Egani (Tavoy) Mining Co., Ltd.	Do.	P L. .	108	4th December 1913	Do.
Do . .	(259) Messrs. The Tenasserim Concessions, Ltd.	Do. .	P. L. (renewal).	904	19th June 1913.	Do.
Do. . .	(260) Chu Lu Yin . .	Do. .	P. L. (renewal).	1,387	17th June 1913.	Do.
Do. . .	(261) Messrs. The Tavoy Concessions, Ltd.	Do. .	P. L. (renewal).	1,570	21st June 1913.	Do.
Do. .	(262) Messrs The Wagon Pachaung Wolfram Mines, Ltd	Do. .	P. L. (renewal).	1,564·4	26th August 1913.	Do.
Do. . .	(263) Leong Shwe Sin .	Do. .	P. L. (renewal).	1,132	8th December 1912.	Do.
Do. . .	(264) Khoo Kim Cheng .	Do. .	P. L. (renewal).	3,200	6th January 1913.	Do.
Do. . .	(265) Maung Ni Toe .	Do. .	P. L. (renewal).	1,174·4	28th February 1913.	Y. M. D. 1—2—25
Do. . .	(266) Messrs. The Tavoy Concessions, Ltd.	Do. .	P. L. (renewal).	2,943	28th February 1913.	1 year.
Do. . .	(267) E Ahmed . .	Do. .	P. L. (renewal).	1,665	23rd March 1913.	Do.
Do. . .	(268) Tan Shwe Cho .	Do. .	P. L. (renewal).	2,756	16th May 1913.	Do.
Do. . .	269) Do. .	Do. .	P. L. (renewal).	3,003	16th May 1913.	Do.
Do. . .	(270) Messrs. The Rangoon Mining Co., Ltd.	Do. .	P. L. (renewal).	2,810	22nd July 1913.	Do.
Do. . .	(271) Maung Shwe Goh .	Do. .	P. L. (renewal).	4,159	18th September 1913.	Do.
Do. . .	(272) Lim Kyee Yan .	Do. .	P. L. (renewal).	1,420·80	19th August 1913.	Do.
Do. . .	(273) San Saing Tin .	Do. .	P. L. (renewal).	775	8th September 1913.	Do.
Do. . .	(274) Messrs. The Tavoy Concessions, Ltd.	Do. .	P. L. (renewal).	1,434	30th August 1913.	Do.
Do. . .	(275) Do. .	Do. .	P. L. (renewal).	2,086	10th September 1913.	6 months.
Do. . .	(276) Leibaoak Syndicate	Do. .	P. L. (renewal).	138 65	4th October 1913.	1 year.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy . .	(277) Mr. P. P. Murphy	All minerals (except mineral oil).	P. L. (renewal).	689 16	4th October 1913.	1 year.
Thaton .	(278) Mr. H. Watson .	Do. .	P. L. .	396·8	20th February 1913.	Do.
Do. .	(279) Maung Pu . .	Do. .	P. L. .	3,104	20th September 1913.	Do.
Do. .	(280) S. Le Fevre . .	Do. .	P. L (renewal).	716 8	9th October 1913.	Do.
Thayetmyo .	(281) Maung Kyan Baw.	Mineral oil . .	P. L. .	640	8th November 1912.	Do.
Do. .	(282) Do. . .	Do. . .	P. L. .	640	8th November 1912.	Do.
Do. .	(283) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. (renewal).	2,560	23rd October 1912.	Do.
Do. .	(284) Maung Tun . .	Do. . .	P. L. (renewal).	222 80	13th December 1912.	Do.
Do .	(285) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. (renewal).	5,760	6th January 1913.	Do.
Do. .	(286) Col. S. G. Radcliff, I.A. (retired).	Do. . .	P. L. .	2,304	19th April 1913.	Do.
Do. .	(287) Do. .	Do. . .	P. L. .	5,280	19th April 1913.	Do.
Do. .	(288) Do. .	Do. . .	P. L. .	5,760	19th April 1913.	Do.
Do. .	(289) Maung Po Kyaw .	Do. . .	P. L. .	2,624	16th May 1913.	Do.
Do. .	(290) Ismail Abu Ahmed	Do. . .	P. L. .	2,880	25th February 1913	Do
Do. .	(291) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. .	960	6th June 1913	Do
Do. .	(292) Do. .	Do. . .	P. L. .	1,280	22nd April 1913	Do.
Do. .	(293) Do.	Do. . .	P. L. .	1,920	26th April 1913.	Do.
Do. .	(294) Maung Thu Daw .	Do. . .	P. L. (renewal).	3,002 80	13th December 1912.	Do.
Do. .	(295) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. (renewal).	4,480	30th May 1913.	Do.
Do. .	(296) Messrs. The British Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	94 72	22nd May 1913.	Do.
Do. .	(297) Shahabuddin .	Do. . .	M. L. .	1,190	2nd June 1912.	30 years.
Do. .	(298) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. (renewal).	3,200	23rd October 1913.	1 year.

E. L.—*Exploring License.* P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thayetmyo .	(299) Messrs. The Burma Oil Co., Ltd.	Mineral oil .	P. L. (renewal).	640	23rd October 1913.	1 year.
Do. .	(300) Do. .	Do. . .	P. L. (renewal).	2,560	23rd October 1913.	Do.
Toungoo .	(301) Maung Po Tha .	Gold, silver, tin, iron and wolfram.	P. L. (renewal).	1,600	10th January 1913.	Do.
Do. .	(302) Do. .	Do. .	P. L. (renewal).	1,600	21st August 1913.	Do.
Upper Chindwin.	(303) Osman Musti Khan & Co., Rangoon.	Mineral oil . . .	P. L. .	3,840	19th February 1913	Do.
Do. .	(304) Gowri Shanker Alweshwar.	Coal . . .	P. L. .	1,280	28th January 1913.	Do.
Do. .	(305) Do. .	Do. . .	E. L. .	3,840	28th January 1913.	Do.
Do. .	(306) Mani Lal . .	Mineral oil . .	E. L. .	10,240	29th August 1913.	Do.
Do. .	(307) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. .	3,200	1st October 1913.	Do.
Do. .	(308) Do. .	Do. . .	P. L. .	3,200	1st October 1913	Do.

CENTRAL PROVINCES.

Balaghat .	(309) The Tata Iron and Steel Company, Ltd.	Manganese . .	M. L. .	680	17th March 1913.	5 years.
Do. .	(310) The Indian Mineral Mining Syndicate.	Do. . .	P. L. .	147	9th January 1913.	1 year.
Do. .	(311) Do. .	Do. . .	P. L. .	255	18th January 1913.	Do.
Do. .	(312) Do. .	Do. . .	P. L. .	131	9th January 1913.	Do.
Do. .	(313) Babu Kripa Shankar.	Do. . .	M. L. .	41	10th February 1913.	30 years.
Do. .	(314) Mr. P. C. Dutt .	Bauxite . .	E. L. .	19,698	23rd January 1913.	1 year.
Do. .	(315) Do. .	Do. . .	E. L. .	8,551	23rd January 1913.	Do.
Do. .	(316) Indian Mineral Mining Syndicate.	Manganese .	P. L. .	7	9th January 1913.	Do.
Do. .	(317) Mr. Byramji Pestonji.	Do. . .	P. L. .	5	20th February 1913.	Do.
Do. .	(318) Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. .	70	17th March 1913.	Do.

E. L.=*Exploring License.* P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(319) Mr. M. B. Dadabhoy, C.I.E.	Manganese .	P. L. .	10	17th March 1913.	1 year.
Do. .	(320) Do. .	Do. . .	P. L. .	36	18th January 1913.	Do.
Do. .	(321) Indian Manganese Co. Ltd.	Do. . .	P. L. .	40	18th January 1913.	Do.
Do. .	(322) Babu Kripa Shankar	Do. . .	E. L. .	68	20th February 1913.	Do.
Do. .	(323) Indian Mineral Mining Syndicate.	Do. . .	P. L. .	106	19th April 1913.	Do.
Do. .	(324) Khan Bahadur M. M. Mulina.	Do. . .	P. L. .	187	19th May 1913	Do.
Do. .	(325) Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. .	41	3rd May 1913	Do.
Do. .	(326) Indian Manganese Co. Ltd.	Do. . .	P. L. .	34	12th June 1913.	Do
Do. .	(327) Do. .	Do. . .	P. L. .	54	19th May 1913.	Do.
Do. .	(328) Mr. M. B. Dadabhoy, C.I.E.	Do. . .	E. L. .	83	12th June 1913.	Do.
Do. .	(329) Indian Manganese Co. Ltd.	Do. . .	E. L. .	10	12th June 1913.	Do.
Do. .	(330) Sir Kasturchand Daga, K.C.I.E.	Do. . .	P. L. .	912	11th September 1913.	Do.
Do. .	(331) Babu Kripa Shankar.	Do. . .	P. L. .	189	1st July 1913	Do.
Do. .	(332) Mr. M. B. Chopra	Do. . .	M. L. .	67	14th July 1913	30 years.
Do. .	(333) Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. .	62	5th August 1913.	1 year.
Do. .	(334) Indian Mineral Mining Syndicate.	Do. . .	P. L. .	23	5th August 1913.	Do.
Do. .	(335) Mr. D. W. A. Macdonald.	Bauxite . .	E. L. .	7,313	2nd September 1913.	Do.
Do. .	(336) Mr. P. C. Dutt .	Do. . .	E. L. .	17,916	11th September 1913.	Do.
Do. .	(337) Sir Kasturchand Daga, K.C.I.E.	Manganese . .	P. L. (renewal).	130	22nd August 1913.	6 months.
Do. .	(338) Babu Kripa Shankar.	Do. . .	P. L. (renewal).	87	11th September 1913.	Do.
Do. .	(339) Do. .	Do. . .	P. L. (renewal).	621	23rd September 1913.	Do.
Do. .	(340) Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. (renewal).	34	22nd August 1913.	Do.
Do. .	(341) Do. .	Do. . .	P. L. (renewal).	84	22nd August 1913.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat	(342) Mr. M. B. Dadabhoy, C.I.E.	Manganese	P. L. (renewal).	13	22nd August 1913.	6 months.
Do.	(343) Indian Mineral Mining Syndicate.	Do.	P. L. (renewal).	7	9th January 1914.	3 months.
Betul	(344) Seth Lakhmichand	Graphite	P. L.	37	15th February 1913.	1 year.
Do.	(345) Do.	Mica	E. L.	555	15th February 1913.	Do.
Do.	(346) Do.	Do.	E. L.	1,100	15th February 1913.	Do.
Do.	(347) Messrs. Nazar Ali and Muhammad Hussain.	Do.	P. L.	180	26th February 1913.	Do.
Do.	(348) Do.	Do.	P. L.	100	27th February 1913.	Do.
Do.	(349) Seth Lakhmichand	Do.	P. L.	245	15th February 1913.	Do.
Do.	(350) Do.	Do.	P. L.	555	16th June 1913.	Do.
Do.	(351) Mr. A. Hanmant Rao.	Graphite	M. L.	20	8th August 1913.	30 years.
Bhandara	(352) Mr. John Grossman	Manganese	P. L.	122	1st March 1913.	1 year.
Do.	(353) Mr. Byramji Pestonji.	Do.	P. L.	13	13th February 1913.	Do.
Do.	(354) Seth Gowardhan Das.	Do.	P. L.	97	12th March 1913.	Do.
Do.	(355) Mr. Byramji Pestonji.	Do.	M. L.	2	10th December 1912.	5 years.
Do.	(356) Mr. L. R. Ramchandra & Co.	Do.	M. L.	55	22nd February 1913.	30 years.
Do.	(357) Indian Manganese Co. Ltd.	Do.	E. L.	67	14th January 1913	1 year.
Do.	(358) Indian Mineral Mining Syndicate.	Do.	P. L. (renewal).	124	19th March 1913.	6 months.
Do.	(359) Mr. Byramji Pestonji.	Do.	M. L.	9	12th April 1913.	5 years.
Do.	(360) Mr. M. B. Dadabhoy, C.I.E.	Do.	P. L.	196	28th August 1913.	1 year.
Do.	(361) Mr. Byramji Pestonji.	Do.	P. L.	240	2nd July 1913	Do.
Do.	(362) Central India Mining Co., Ltd.	Do.	P. L.	19	28th August 1913.	Do.
Do.	(363) Seth Mahadeo	Do.	P. L.	257	20th October 1913.	Do.
Do.	(364) Seth Gowardhan Das.	Do.	P. L.	157	27th October 1913.	Do.

E. L.=*Exploring License.* P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bhandara .	(365) Seth Gowardhan Das.	Manganese . .	E. L. .	94	3rd November 1913.	1 year.
Bilaspur .	(366) Mr. W. J. Considine	Coal and other minerals.	E. L. .	1,863	23rd January 1913.	Do.
Do. .	(367) Do. .	Coal and iron .	P. L. (renewal).	11,623	26th March 1913.	Do.
Do. .	(368) Do. .	Coal . . .	E. L. .	13,301	19th June 1913.	Do.
Do. .	(369) Do. .	Do. . . .	E. L. .	19,532	19th June 1913.	Do.
Chanda .	(370) Chanda Coal Prospecting Syndicate.	Do. . . .	M. L. .	240	4th April 1913	30 years.
Do. . .	(371) Do. .	Do. . .	M. L. .	473	7th April 1913	Do.
Do. .	(372) Sir Kasturchand Daga, K.C.I.E., and Mr. M. B. Dadabhoy, C.I.E.	Do. . .	M. L. .	1,280	1st April 1913	Do.
Do. . .	(373) Chanda Coal Prospecting Syndicate.	Do. . .	M. L. .	391	7th July 1913	Do.
Do. . .	(374) Sir Kasturchand Daga, K.C.I.E., and Mr. M. B. Dadabhoy, C.I.E.	Do. . .	E. L. .	3,276	29th August 1913.	1 year.
Do. . .	(375) Do. .	Do. . .	P. L. .	1,031	6th November 1913.	Do.
Chhindwara .	(376) Indian Manganese Co., Ltd.	Manganese . .	P. L. .	200	18th February 1913.	Do.
Do. .	(377) Mr. M. B. Dadabhoy, C.I.E.	Do. . .	M. L. .	7	11th January 1913.	5 years.
Do. .	(378) Khan Bahadur Ali Raza Khan.	Coal . . .	P. L. .	495	13th March 1913.	1 year.
Do. .	(379) Messrs. H. Verma and Kanhaiyalal.	Manganese . .	P. L. (renewal).	381	19th January 1913.	6 months.
Do. .	(380) Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. (renewal).	220	30th January 1913.	Do.
Do. .	(381) Do. .	Do. . .	P. L. (renewal).	106	1st April 1913	Do.
Do. .	(382) Messrs. H. Verma and Kanhaiyalal.	Coal . . .	E. L. .	8,639	21st May 1913	1 year.
Do. . .	(383) Do. .	Do. . .	E. L. .	3,318	28th April 1913.	Do.
Do. .	(384) Do. .	Manganese . .	P. L. (renewal).	463	10th May 1913	Do.
Do. .	(385) Indian Manganese Co., Ltd.	Do. . .	P. L. .	65	23rd July 1913	Do.

E. L.=*Exploring License.* P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chhindwara .	(386) Mr. H. Verma and Munshi Kanhaiyalal.	Manganese . .	P. L. .	204	13th September 1913.	1 year.
Do. .	(387) Do. .	Do. . .	P. L. .	164	13th September 1913.	Do.
Do. .	(388) Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. (renewal).	58	27th June 1913	6 months.
Do. .	(389) Do. .	Do. . .	P. L. (renewal).	159	27th July 1913	Do.
Do. .	(390) Mr. H. Verma and Munshi Kanhaiyalal.	Coal . . .	E. L. .	3,046	5th August 1913.	1 year.
Do. .	(391) Mr. M. B. Dadabhoy, C.I.E.	Manganese . .	P. L. (renewal).	213	8th July 1913	6 months.
Jubbulpore .	(392) Messrs. Olpherts & Co.	Manganese, copper, gold and silver.	P. L. .	653	21st June 1913.	1 year.
Do. .	(393) Mr. P. C. Dutt .	Bauxite . .	P. L. .	1,352	3rd May 1913	Do.
Do. .	(394) Do. .	Bauxite and manganese.	E. L. .	6,220	23rd May 1913	Do.
Do. .	(395) Do. .	Iron and bauxite .	E. L. .	6,815	27th June 1913.	Do.
Do. .	(396) Do. .	Do. .	P. L. .	71	21st August 1913.	Do.
Do. .	(397) Do. .	Iron, bauxite, manganese and copper.	E. L. .	1,827	13th September 1913.	Do.
Do. .	(398) Do. .	Iron and bauxite .	E. L. .	7,021	13th August 1913.	Do.
Do. .	(399) The Katni Cement and Industrial Co., Ltd.	Soapstone, steatite and talc.	M. L. .	32	15th October 1913.	30 years.
Do. .	(400) Mr. S. P. Dutt .	Copper, barytes, galena, manganese and mica.	E. L. .	1,434	24th November 1913.	1 year.
Do. .	(401) Mr. J. C. Mance .	Bauxite . .	E. L. .	1,250	8th November 1913.	Do.
Nagpur .	(402) Nagpur Manganese Mining Syndicate.	Manganese .	P. L. .	80	3rd March 1913.	Do.
Do. .	(403) Central India Mining Co., Ltd.	Do. . .	M. L. .	19	2nd January 1913.	30 years.
Do. .	(404) Mr. T. Cuverji Bhoja.	Do. . .	M. L. .	33	18th January 1913.	Do.
Do. .	(405) Mr. Lakshman Damodar Lele.	Do. . .	P. L. (renewal).	12	25th October 1913.	1 year.
Do. .	(406) Mr. Khimji Cuverji	Do. . .	E. L. .	80	11th March 1913.	Do.
Do. .	(407) Mr. Lakshman Damodar Lele.	Do. . .	E. L. .	170	7th February 1913.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(408) Mr. Lakshman Damodar Lele.	Manganese . .	E. L. .	155	15th March 1913.	1 year.
Do. .	(409) Do. .	Do. . .	E. L. .	1	29th March 1913.	Do.
Do. . .	(410) Indian Manganese Co., Ltd.	Do. . .	P. L. .	74	18th June 1913.	Do.
Do. .	(411) Mr. Byramji Pestonji.	Do. . .	P. L. .	26	29th April 1913.	Do.
Do. . .	(412) Mr. Lakshman Damodar Lele.	Do. . .	P. L. (renewal).	89	27th September 1913.	Do.
Do. . .	(413) Mr. A. Hanmant Rao.	Do. . .	P. L. (renewal).	163	4th November 1913.	Do.
Do. . .	(414) Do. .	Do. . .	P. L. (renewal).	Not stated .	29th January 1913.	Do.
Do. . .	(415) Mr. Lakshman Damodar Lele.	Do. . .	P. L. (renewal).	108	4th January 1913.	Do.
Do. . .	(416) Seth Jaitmal Ramkaran.	Do. . .	E. L. .	70	23rd May 1913	Do.
Do. . .	(417) Mr. Lakshman Damodar Lele.	Do. . .	P. L. .	1	31st May 1913	Do.
Do. . .	(418) Mr. Byramji Pestonji.	Coal . . .	E. L. .	653	25th June 1913.	Do.
Do. . .	(419) Mr. Hariram Sitaram Patel.	Manganese . .	P. L. .	356	11th June 1913	Do.
Do. . .	(420) Messrs. K. Nawal Singh & Co.	Do. . .	E. L. .	39	23rd May 1913	Do.
Do. . .	(421) Seth Ram Chandra	Do. . .	E. L. .	31	18th June 1913.	Do.
Do. . .	(422) Central Provinces Prospecting Syndicate, Ltd.	Do. . .	M. L. .	10	5th August 1913.	Will expire with the original lease dated 31st July 1901, to which it is supplementary.
Do. . .	(423) Mr. Lakshman Damodar Lele.	Do. . .	P. L. .	105	23rd August 1913.	1 year.
Do. . .	(424) Nagpur Manganese Mining Syndicate.	Do. . .	P. L. (renewal).	13	9th February 1913.	7 months, 22 days.
Do. . .	(425) Do. .	Do. . .	P. L. (renewal).	30	9th February 1913.	1 year.
Do. . .	(426) Messrs. Schröder, Smidt & Co.	Do. . .	P. L. (renewal).	243	3rd February 1913.	Do.
Do. . .	(427) Mr. P. Balkrishna Naidu.	Do. . .	P. L. (renewal).	214	23rd March 1913.	6 months.

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CENTRAL PROVINCES—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(428) Messrs. Radhakisan Brothers.	Manganese .	P. L. (renewal).	186	23rd March 1913.	6 months.
Do. . .	(429) Do. .	Do. . .	P. L. (renewal).	56	23rd March 1913.	9 months.
Do. . .	(430) Nagpur Manganese Mining Syndicate.	Do. . .	E. L. .	52	4th July 1913	1 year.
Do. . .	(431) Do. .	Do. . .	P. L. .	40	24th April 1913.	Do.
Do. . .	(432) Mr. Lakshman Damodar Lele	Do. . .	P. L. (renewal).	52	23rd April 1913.	Do.
Do. . .	(433) Seth Mahanandram Sheonarayan.	Do. . .	P. L. (renewal).	83	20th May 1913.	9 months.
Do. . .	(434) Mr. P. Balkrishna Naidu.	Do . .	P. L. (renewal).	106	16th May 1913.	7 months and 16 days.
Do . .	(435) Messrs. Radhakisan Brothers.	Do. . .	P. L. (renewal).	490	16th May 1913.	7 months and 16 days.
Do. . .	(436) Seth Ramcharan .	Do. . .	P. L. .	31	23rd August 1913.	1 year.
Do. . .	(437) Mr. P. Balkrishna Naidu.	Do. .	P. L. (renewal).	160	7th June 1913	Do.
Do. . .	(438) Indian Mineral Mining Syndicate.	Do. . .	P. L. (renewal).	136	8th July 1913	2 months.
Do. . .	(439) Mr. P. Balkrishna Naidu.	Do. . .	P. L. (renewal).	467	26th August 1913.	1 year.
Do. . .	(440) Do .	Do. . .	P. L. (renewal).	155	28th August 1913.	Do.
Do. .	(441) Nagpur Manganese Mining Syndicate.	Do. . .	E. L. .	192	14th October 1913.	Do.
Do. . .	(442) Mr. Gosai Ramkrishnapuri.	Not stated . .	E. L. .	343	14th October 1913.	Do.
Do. . .	(443) Do. .	Do. . .	E. L. .	62	14th October 1913.	Do.
Do. . .	(444) Mr. A. Hanmant Rao.	Manganese . .	P. L. (renewal).	163	4th November 1913.	Do.
Do. . .	(445) Do. .	Do. . .	P. L. (renewal).	74	29th January 1914.	Do.
Raipur . .	(446) Mr. T. B. Kantharia	Graphite . .	E. L. .	Entire village	4th February 1913.	Do.
Do. . .	(447) Do. .	Do. . .	P. L. (renewal).	351	14th October 1913.	Do.
Seoni . .	(448) Seth Gowardhan Das.	Mica . .	P. L. .	90	4th February 1913.	Do.

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MADRAS.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Anantapur .	(449) Mr. A. Ghose .	All minerals .	E. L. .	The whole of Gooty and Tadpatri taluks exclusive of patta, private and inam lands.	13th March 1913.	1 year.
Bellary . .	(450) Do. .	Manganese . .	P. L. .	319·19	18th March 1913.	Do.
Do. . .	(451) Do. .	Iron-ore, manganese, copper, graphite and ochre.	P. L. .	2,585·88	9th June 1913.	Do.
Do. . .	(452) A. M. Jeevanji & Co., Bombay.	Certain minerals for colours.	P. L. .	260·00	Not stated .	Not stated.
Do. . .	(453) Do. .	Do. .	P. L. .	275·50	Do. .	Do.
Coimbatore .	(454) C. V. Narasaiah, Esq., Bar.-at-Law.	Mica . . .	M. L. .	211·92	30th September 1913.	30 years.
Do.	(455) Do. .	Do. . . .	M. L. .	7·78	30th September 1913.	Do.
Do. .	(456) Mr. H. A. Brandt	Do. . . .	M. L. .	14·11	28th September 1913.	Do.
Do. .	(457) Do. .	Do. . . .	M. L. .	4·37	30th September 1913.	Do.
Godavari .	(458) Mr. Fred Cross .	Plumbago . .	P. L. .	1,280	4th April 1913	1 year.
Do. .	(459) Hyderabad (Deccan) Co., Ltd.	Coal . . .	E. L. .	Not mentioned	15th May 1913	Do.
Kurnool .	(460) Mr. A. Ghose and Mr. Charles Jambon.	Steatite and magnesite.	M. L. .	161·00	5th March 1913.	30 years.
Do. .	(461) Mr. A. Peston Jamas.	Diamonds . .	P. L. .	682·22	14th May 1913.	1 year.
Do. .	(462) Do. .	Do. . .	P. L. .	342·15	Do. .	Do.
Do. .	(463) Do. .	Do. . .	P. L. .	274·25	Do. .	Do.
Do. .	(464) Do. .	Do. . .	P. L. .	442·00	Do. .	Do.
Do. .	(465) Messrs. A. Ghose and C. Jambon.	Lead-ores . .	M. L. .	19·11	12th July 1913.	30 years.
Do. .	(466) Mr. A. Ghose .	Diamond . .	P. L. .	1,075·78	23rd October 1913.	1 year.
Do. .	(467) Do. .	Do. . .	P. L. .	567·45	22nd October 1913.	Do.
Nellore . .	(468) Raja Vasi Reddi Sri Chandra Mauleswara Prasad Bahadur.	Mica . . .	P. L. .	22·66	9th July 1912.	Do.

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MADRAS—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore . .	(469) Gurizala Subrahmanyam.	Mica . . .	M. L. .	7·86	28th November 1912.	30 years.
Do. . .	(470) Kandumur Rama Chandrayya.	Do. . .	P. L. .	17·95	31st August 1912.	1 year.
Do. . .	(471) Mr. H. A. Brandt .	Do. . .	M. L. .	28·78	3rd February 1913.	30 years.
Do. . .	(472) Kandumur Rama Chandrayya.	Do. . .	P. L. .	10·84	31st August 1912.	1 year.
Do. . .	(473) Mr. Fred Cross .	Do. . .	P. L. .	13·05	2nd October 1912.	Do.
Do. . .	(474) Mr. H. A. Brandt .	Do. . .	P. L. .	52·93	1st December 1912.	Do.
Do. . .	(475) Do. .	Do. . .	P. L. .	57·88	1st December 1912.	Do.
Do. . .	(476) Lt.-Col. M. E. Reporter.	Do. . .	P. L. .	16·20	3rd February 1913.	Do.
Do. . .	(477) P. V. Krishna Rao	Do. . .	P. L. .	13·25	7th September 1912.	Do.
Do. . .	(478) T. R. Tawker & Sons.	Do. . .	E. L. .	Not mentioned	4th January 1913.	Do.
Do. .	(479) V. Ranga Reddi .	Do. . .	E. L. .	Do. .	Do. .	Do.
Do. . .	(480) Messrs. A. M. Jeevanji & Co.	Do. . .	E. L. .	Do. .	20th April 1913.	Do.
Do. . .	(481) Gurizala Subrahmanyam.	Do. . .	E. L. .	Do. .	15th May 1913.	Do.
Do. . .	(482) Mr. James Short .	Do. . .	M. L. .	276·61	11th November 1911.	30 years.
Do. . .	(483) P. Krishnaswami Madaliyar.	Do. . .	P. L. .	36·50	3rd October 1912.	1 year.
Do. . .	(484) Mr. H. A. Brandt	Do. . .	P. L. .	19·96	1st April 1913.	Do.
Do. . .	(485) Do. .	Do. . .	P. L. .	11·60	1st April 1913	Do.
Do. . .	(486) Lt.-Col. M. E. Reporter, I.M.S. (Retired).	Do. . .	M. L. .	113·12	21st April 1913.	30 years.
Do. . .	(487) P. Krishnaswami Madaliyar.	Do. . .	P. L. .	22·58	23rd April 1913.	1 year.
Do. . .	(488) Mr. H. A. Brandt .	Do. . .	P. L. .	118·50	19th July 1913.	Do.
Do. . .	(489) Do. .	Do. . .	P. L. .	97·20	31st July 1913.	Do.
Do. . .	(490) G. Subrahmanyam	Do. . .	M. L. .	20·10	4th February 1913.	30 years.
Do. . .	(491) V. Ranga Reddi .	Do. . .	P. L. .	17·46	1st August 1913.	1 year.
Trichinopoly .	(492) H. G. Turner, Esq. (by Robert O'Connell, Esq.)	Phosphatic nodules	P. L. .	4,498·75	5th July 1913	Do.

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NORTH-WEST FRONTIER PROVINCE.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kohat . .	(493) Mr. R. A. Prideaux	Mineral oil .	E. L. .	3,200	5th August 1913.	1 year.

PUNJAB.

Mianwali .	(494) Colonel P. H. H. Massy, I.A. (Retired).	Mineral oil . .	P. L. .	3,200	8th May 1913	1 year.
Rawalpindi .	(495) Messrs. N. D. Hari Ram and Brothers on behalf of Colonel Percy H. H. Massy.	Do. . .	P. L. .	112,797	30th January 1913.	Do.

SUMMARY.

Provinces.	Prospecting Licenses.	Exploring Licenses.	Mining Leases.	Total of each Province.
Assam	9	..	..	9
Baluchistan	..	..	5	5
Bengal	4	..	1	5
Bihar and Orissa	13	..	10	23
Bombay	1	..	..	1
Burma	240	9	16	265
Central Provinces	87	37	16	140
Madras	27	6	11	44
North-West Frontier Province	..	1	..	1
Punjab	2	.	..	2
Totals for each kind and Grand Total, 1913 .	383	53	59	495
Total for 1912 .	487	75	60	622

E. L.=*Exploring License.* P. L.=*Prospecting License.* M. L.=*Mining Lease.*

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1914. [November.

SOME NEWLY DISCOVERED COAL-SEAMS NEAR THE YAW RIVER, PAKOKKU DISTRICT, UPPER BURMA. BY G. DE P. COTTER, B.A. (DUB.), F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 5-12.)

Introduction.

IN the first quarter of 1913, I geologically mapped part of the Pakokku district in the Pauk sub-division, which is traversed by the Yaw River, and affords an excellent section through the Tertiary rocks of Burma. A topographical map on a scale of 1 inch =1 mile is published by the Survey of India and is numbered Sheet 84, K-7.

I have already alluded to this area in a paper entitled "Notes on the value of Nummulites as Zone Fossils" (*Rec. Geol. Sur. Ind.*, Vol. XLIV, p. 52).

In the sandstones overlying the nummulitic shales which in the above quoted paper I termed the Yaw stage, I found numerous coal-seams. The examination of these was postponed till the following field season, but I collected one specimen from a seam exposed close to Tazu village. It gave the following proximate analysis:—

Moisture	16·88
Volatile matter	38·10
Fixed carbon	35·72
Ash	9·30
	100·00

In Februray 1914, I showed these coal-seams to Dr. H. H. Hayden, Director, Geological Survey of India, and received instructions to open up the seams and to measure and sample them. Mr. Sethu Rama Rau, Sub-Assistant, Geological Survey, was deputed to assist me in the work, which was commenced on the 16th of March and completed in a month. The present paper sets forth the results of our examination.

In all twenty-two average samples were obtained. Each sample was taken by cutting out the coal in a regular groove from the top to the bottom of the seam, by handpicking and rejecting all clay partings, and by subsequent coning and halving. Five sketch maps of the more important exposures were made; the sketch map of the Yekyin Chaung (plate 11, fig. 3) has been prepared by the plane-table and steel tape, while the remaining maps were made by pacing and pocket-compass. Mr. Sethu Rama Rau is responsible for the sketch maps of the Thongwa and the Newe Chaungs.

Geology and structure.

The geology and structure of the area can be seen from an examination of the map and sections accompanying this paper (plates 9 and 10). The formations mapped are :—

I. Recent Alluvium.	IV. Yaw Shales.
II. Irrawaddy Sandstones.	V. Pondaung Sandstones.
III. Pegu Series.	VI. Tabyin Clays.

When examining the Yaw River section, I was unable to map with certainty the same boundaries as those previously mapped in the Minbu district (see my paper entitled "The Pegu-Eocene Succession in the Minbu district near Ngape, *Rec. Geol. Sur. Ind.*, Vol. XLI, p. 221). This was owing to the fact that the intervening country had not been mapped. From an examination of the foraminifera and mollusca of the Yaw Shales, I regarded them as the same in age as the *Velates schmiedeli* zone of Minbu, which I described in the above quoted paper. This conjecture was subsequently corroborated by my colleague Mr. H. S. Bion, who last field-season mapped the intervening country between the Minbu section and the Yaw River section, and who found that the *Velates* zone comes stratigraphically on the top of the Yaw stage, so that the top of the Yaw Shales corresponds to the *Velates* zone of Minbu.

The Pegu Series therefore, as mapped in this area, actually do correspond in their upper and lower limits with the Pegus as

mapped in the Ngape section in Minbu. They include the upper Pegus, which in Minbu are highly fossiliferous sands and thin shales; the clays and shales, which contain *Lepidocyclina theobaldi* and other foraminifera, and which I conjectured might correspond to the Sitsayan Shales of Lower Burma, and the sandstones underlying them, containing the fossil-beds which I marked D, E, and F. But although the Pegu series can be separated into these three sub-divisions in the Ngape section, such sub-division becomes impossible in the Yaw section, since the upper Pegus have become fluviatile, the *Lepidocyclina theobaldi* clays have disappeared and are represented by sands, similar to those above and below, while the underlying sandstones contain only fresh or brackish water fossils such as *Cyrena*. Sub-division is therefore impossible on the lines adopted in Minbu.

My colleagues Mr. G. H. Tipper, Mr. H. S. Bion and myself have decided to use the terms Pegus (restricted), Padaung Clays, and Shwezetaw Sandstones to indicate each of the three sub-divisions of the Pegus mentioned above. The name Padaung is taken from a village situated upon the *L. theobaldi* clays and marked on the map accompanying my paper on the Ngape section. The name Shwezetaw is taken from a famous pagoda of that name at the village of Payaywa which will also be found marked on the same map.

The coal-bearing sandstones of the Yaw River section correspond to the lowest of these three sub-divisions, *viz.*, the Shwezetaw Sandstones, which contain the fossil beds marked D, E, and F on my map.

The Yaw stage corresponds to the *Velates schmiedeli* zone and some of the beds below it, while the Pondaung sandstones correspond to the massive sandstones which form the Nwamataung Hill-Range, and which in Minbu contain the bed H. The Tabyin Clays are largely concealed by soil and alluvium in Minbu. The Yaw Shales, Pondaung Sandstones and Tabyin Clays are all Eocene in age.

The whole series from the base of the Irrawaddy Sands to the base of the Eocene, I believe to be conformable. There is certainly no discordance of dip at any part of the series. It is likely, however, that there has been an interruption of sedimentation at many horizons causing what may be termed local unconformities. The Irrawaddy basin during tertiary times was a geosynclinal area, and we may suppose that the geosyncline continued to subside slowly

throughout the Tertiary period. When the rate of deposition was faster than the rate of subsidence, we find very shallow water deposits, with much local unconformity, using the word in the sense of interruption of sedimentation; these local unconformities doubtless indicate the emergence of land in the Tertiary sea. But this emergence of land must not be taken as indicating an upheaval, but as merely a retardation of subsidence, so that the sediments have had time to fill up the sea locally. We must recognise also that the Pegu and Irrawaddy Series are regressive series, and that the change from marine deposits in the Pegus of the south of Burma to the entirely fluviatile or very shallow water deposits of the Pegus of the Yaw River section in Pakokku indicates a gradual retreat of the Tertiary sea to the south. Each bed may be regarded as imperceptibly regressive from the immediately underlying one.

This state of affairs gives rise to a regular lateral variation in each bed. Thus the Padaung Clays are deep water clays with limestone in the Ngape section. At Ngahlaingdwin in the north of Minbu, there is no intercalated limestone, but the clays are still well developed. Finally the clays grade into sands about the latitude of the Saw-Seikpyu road in the south of Pakokku as my colleague Mr. H. S. Bion has shown. In the Yaw section nothing but current-bedded sandstones are found at this horizon.

I have frequently observed also that many beds when traced northwards, after passing through the current-bedded sand phase, finally end up as red earth beds or ferruginous conglomerates, and become indistinguishable from those of the Irrawaddy series, so that it becomes a matter of extreme difficulty to draw geological boundaries near the flanks of the geosyncline.

The hypothesis that the Pegus and the Irrawaddies are both regressive series is well supported by the results of field work in Minbu and Pakokku. It would be incompatible with this hypothesis to suppose that the Irrawaddies could in these districts be transgressive or could overlap the Pegus. Possibly cases of supposed overlap may be really explained as erroneous mapping of different red earth beds as being one and the same horizon.

Geological boundaries.

The geological boundaries mapped in this area are not always well defined in the field, and a few descriptive remarks are necessary. The boundary of the Irrawaddies and the Pegus is a red earth bed, continuous over the whole of the sheet, over 100 ft., thick in most exposures,

often containing white pebbles, and on the whole an easily mapped horizon. From Mr. Bion's work, I believe it to be approximately the same horizon as that mapped in the Ngape section of Minbu. The upper and lower boundaries of the Padaung Clays are obliterated, but just above this horizon, there is a well defined stratum of ferruginous conglomerate which is developed in the north of the sheet. The boundary of the Pegus and the Yaw stage is somewhat ill defined in the south of the sheet. The Pegus as a whole are sandstones, while the Yaws are shales and clays with marine fossils. But on the Pegu-Yaw boundary there are alternates of shale and sand. It is purely a matter of convention as to whether these should be mapped with the Yaws or with the Pegus.

The boundary of the Yaws and the Pondaung sandstones is well defined, and the change from shale to sandstone at this horizon is sharp. The top of the Pondaungs is marked by oil-bearing sandstone. The boundary of the Pondaung sandstone and the Tabyin Clay is certainly the worst and most unreliable boundary in the whole of this area, since the change from the sandstones to the clays is a gradual one. Owing to the heavy soil-cap and dense jungle, one cannot do strike-mapping; it is therefore very easy to map different horizons as one and the same, when traverse-mapping this boundary. In most sections the Tabyin Clays are sheared and rolled by the movement of the massive Pondaung sandstones over them, and show considerable contortion. Dips in these clays are wholly unreliable.

Rolling of strata is also seen in the Yaw Shales exposed in the Yaw River section, but is developed in a much less degree. In the coal-bearing strata in the lower Pegus, rolling is also seen, but is usually slight.

Structure.

The structure can be seen from an examination of the sections on Plate 9. There is a rapidly rising anticline with a syncline to the west. North of the Yaw, this anticline forms the Pondaung range of hills. The anticlinal and synclinal crests become faulted north of the Yaw River, and there is a tendency towards isoclinal structure about two miles north of the river.

The coal-seams may be divided into three areas:—

(1) The seams running from the Yaw River half a mile S. E. of Letpanhla village in a S. W. direction to the crest

of the Pondaung fold. (See Plates 10, 11). The dip varies between 40 degrees at the Yaw River to close on 30 degrees near the crest of the fold.

(2) The seams running from the crest of the Pondaung fold in the Yekyin Chaung, north westwards past Tazu village along the western flank of the anticline. All this coal dips steeply and is usually inclined at angles over 60 degrees. I have not sampled this steeply dipping coal at all. It is much sheared and compressed. A photograph of these seams opposite Tazu village is shown on plate 6.

(3) The seams exposed in the gently dipping western flank of the syncline west of Tazu village. The dip varies from about 10 degrees in the north to about 20 degrees in the south. It has been examined in the Shanthe chaung north of the Yaw River, and in the Kan, Thongwa and Newe Chaungs south of the Yaw River. (See plates 11, 12).

Besides these, I have marked upon the geological map (plate 10) a coal-seam in the Pondaung Sandstones. The occurrence does not appear to be of economic importance, and need not be mentioned again.

I shall describe in detail the seams of the first and third of these areas. For the sake of brevity I shall term the first area the Letpanhla Field, and the third the Tazu Field.

I. The Letpanhla Field.

The seams extend from a point on the Yaw River half a mile S. E. of Letpanhla village to the crest of the Pondaung fold to the south-west. The outcrop is about 1½ miles in length, without reckoning its probable extension some distance north of the Yaw River. But north of the river the seams have not been examined.

A sketch-map on a scale of 16 inches = 1 mile is shown on plate 11, fig. 3. There are a group of thick seams above and numerous minor seams below. The thick upper seams have been excavated at four points marked on the map. Three of these localities are in the

Yekyin chaung and one in the Yaw River. I commence by a description of the most southerly.

Excavation No. 1.—The section is as follows:—

		Ft.	In.
Top of cliff, surface soil and purple shale unestimated.			
Ochreous and carbonaceous shale with three 3″ coal-seams		2	0
Carbonaceous shale with one 1″ seam		1	10
Coal and carbonaceous shale mixed		0	11
Sandy clay		4	7
Coal and Clay mixed		1	4
Ochreous sands		6	9
Coal	Sample No. 1	1	5
Pink Sandstone	Sample No. 1	0	2½
Coal	Sample No. 1	0	8½
Blue clay		3	3
Coal		0	3
Sand		0	3
Coal		0	4½
Carbonaceous shale with one 1″ band of coal		1	2
Coal	Sample No. 2	1	3
Carbonaceous clay	Sample No. 2	0	3
Coal	Sample No. 2	0	6½
Carbonaceous clay		0	2½
Light grey clay		1	0
Coal and clay mixed half and half		0	7
Coal, Sample No. 3		1	2
Carbonaceous clay with thin coal-seams		1	0
Clay and shale with one 1″ band of coal		3	3
Coal with ½″ bed of sand 1″ from bottom		0	7½
Carbonaceous shale with occasional pockets of coal		1	4½
Coal	Sample No. 4	0	4
Clay	Sample No. 4	0	1
Coal	Sample No. 4	2	0
Clay	Sample No. 4	1	0
Coal	Sample No. 4	0	9
Carbonaceous shale with ochre		3	0
Coal, Sample No. 5		3	6
Carbonaceous shale		0	5
Coal		0	4
Carbonaceous shale, bottom unseen but upwards of		1	0

In this section, of a thickness of over 28 ft. of strata nearly 13 ft. are coal. The two best seams are those from which samples 4 and 5 are taken, these two seams together make a thickness of

6 ft. 7 in. of available coal. The numerous partings between the seams are of course a great defect, and would greatly increase the cost of mining. The observed dip was at 29 degrees to 141 degrees east of north. The angles of dip are however not wholly reliable owing to a very slight roll of the strata, and I believe that some angle between 30 and 33 degrees would be more generally correct for this part.

Excavation No. 2.—In this section there are two seams—an upper poorer seam and a lower thick seam, overlain by purple shale with massive sandstone above. The section is as follows:—

		Ft.	In.
Coal, Sample No. 6		1	5
Carbonaceous shale		0	5
Grey sandy clay, about, grading into		3	6
Ochreous clay grading to carbonaceous clay, about		3	6
Coal	Sample No. 7	0	3
Carbonaceous shale		0	3
Coal		2	7
Carbonaceous shale		0	2
Coal		1	1½
Carbonaceous shale		0	1½
Coal		2	4½

Here the partings are thin and of little consequence and the seam may be regarded as Coal 6 ft. 4 in.

Both these seams contain thin plates of gypsum developed along the joint planes. For this reason the coal is apt to split up into small pieces, while it is more compact in Excavation No. 1. There are also in some specimens occasional minute specks of iron pyrites. There is a certain amount of moisture in the joint planes, and no doubt the high percentage of water must be discounted somewhat to allow for percolation of surface water into the seams.

Below this seam in this section the following strata are exposed:—

	Ft.	In.
Blue clay, about	12	0
Carbonaceous clay with strings of coal	2	0
Clay and unseen beds, about	18	0
Carbonaceous clay, bottom unseen but upwards of	3	0

Excavation No. 3—

	Ft.	In.
Massive sandstones with shale bands in the lower 200 feet.		
Poor coal, Sample No. 8	1	6½
Clay, about	6	0
Coal (Sample No. 9)	1	5
Clay (Sample No. 9)	0	1
Coal (Sample No. 9)	0	2
Clay (Sample No. 9)	0	0½
Coal (Sample No. 9)	0	11
Clay (Sample No. 9)	0	1
Coal (Sample No. 9)	1	6
Clay (Sample No. 9)	0	0½
Coal (Sample No. 9)	1	1
Clay (Sample No. 9)	0	0½
Coal (Sample No. 9)	0	8½

Below this, the seam is poor and is as follows :—

	Ft.	In.
Clay	0	1½
Coal	0	2
Clay	0	3
Coal	0	3

This lower part of the seam was not included in the sample. Below this, the section is continued as follows :—

	Ft.	In.
Clays, about	15	0
Carbonaceous shale with strings of coal . . .	2	0
Clay	6	0
Impure coal with clay and ochre, half and half . .	1	9
Light grey clay	1	0
Carbonaceous clay	2	0
Light grey clay, bottom unseen, upwards of . . .	1	0
Unseen beds, about 30 or 35 ft.		
Massive sandstones, with coal-measures containing the lower poorer seams underlying.		

Excavation No. 4 on south bank of Yaw River.—There is a small dip fault in this section, as will be seen from the map. The throw is about 8 ft. Disregarding the fault, the section is:—

		Ft.	In.
Massive fossil wood sandstones.			
Coal		0	10
Carbonaceous shale		0	9
Clay		5	6
Coal	Sample No. 11	1	9
Clay		0	2½
Coal		1	11
Clay		0	1
Coal		0	5½
Impure coal with shale		0	6

Here the main seam is reduced from its former thickness of over 6 ft. to a thickness of 4 ft. 1½ inches of good coal, with 6 inches of impure coal beneath.

Below this seam the section is continued as follows:—

	Ft.	In.
Shales and sandstones, about	13	0
Massive sandstone, about 40 or 45 ft. (see last entry of excavation No. 3).		
Blue Clay, about	3	0
Carbonaceous shales	1	2
Coal with one 1 inch band of clay	1	3
Carbonaceous shale	1	1
Coal	0	8
Shale, carbonaceous in lower part	4	6
Coal and clay mixed	0	5
Carbonaceous clay	1	1
Impure coal	0	3½
Coal, Sample No. 12	1	3½
Blue clay, about	6	0
Impure coal	0	6
Shale	0	2
Coal	0	4
Unseen beds, about	25	0
Blue shale, about	18	0
Coal	1	4
Shale and then sandstone underlie this.		

Other exposures in the Yekyin Chaung.—Some account of the beds above and below the main seams is necessary, in order to indicate the nature of the roof and the floor above and below

the seams, and also to form an estimate of the minor seams below the main seams above described. In the map on plate 11 the various localities in the Yekyin Chaung are indicated by Roman numerals. At I the crest of the Pondaung fold crosses the Yekyin Chaung. Massive sandstones are exposed, containing pockets of coal. The dip of these sandstones west of the crest is at 80 degrees to 200 degrees east of north. The base of these sandstones is seen at II, where there is a waterfall and a deep pool in the chaung. The dip here is at 34 degrees to 120 degrees east of north. The sandstones are here underlain by a bed of carbonaceous shale 3 ft. thick. Below this at III is a bed of purple ochreous shale from 80 to 100 ft. thick. Underlying this comes about 100 ft. of massive fossil wood bearing sandstones. At IV the main seams are very badly exposed, but are seen underlying these sandstones. Further down the chaung, we see the same horizon at Excavation No. 1, which has been already described. The beds underlying the main seams exposed near V are:—

	Ft.	In.
Sand and clay about	11	0
Ochreous and carbonaceous clay with strings of coal .	2	4
Shale, clay and sandstone, ill seen, about . . .	20	0

And at VI, below the above:—

	Ft.	In.
Hard blue clay	2	0
Blue clay and coal, half and half	2	8
Light blue clay	0	9
Impure coal	1	8
Clunchy blue clay, about	4	0
Heliotrope coloured sand and clay, well bedded below, clunchy above, shown on map, about	18	0
Clunchy clay grading into thin bedded carbonaceous clay with ochre, about	9	0
Coal	1	3
Coal and carbonaceous ochreous shale	0	9
Bluish sandy clay, about	25	0

And below this at VII, comes:—

	Ft.	In.
Coal	0	1
Carbonaceous clay	0	3
Coal	0	8
Carbonaceous clay	0	1
Coal	0	10

These last five entries further down the stream are represented by :—

	Ft.	In.
Coal, of which top 4″ is lightly impure	1	2
Carbonaceous shale	0	4
Coal	0	9
Purple shale, about	11	0
Sandstones with many clay partings, about	20	0

And below this at VIII, are seen :—

	Ft.	In.
Carbonaceous shale	0	6
Coal	0	9
Carbonaceous shale	0	7
Coal	0	11

Continuing the section downwards, we have :—

Ochreous shale	13	0
Clay with sandstone lenticles	11	0
Impure coal	0	6
Ochreous shale and clay, about	3	0

And at IX—

Coal	2	1
Unseen beds, roughly about	30	0

And at X, another seam as follows :—

Coal	0	5
Carbonaceous clay	0	9½
Coal	0	6½
Carbonaceous clay	0	10½
Coal	0	8
Carbonaceous shale and clay, bottom unseen.		

These are the lowest beds exposed in the Yekyin Chaung. I have not seen any good coal seams in the beds underlying this lowest seam. The exposures are poor.

Proceeding down stream along the bed of the Chaung, we now recross upwards over the beds above described.

At XI the seam previously seen at X is exposed. At XII the previous entry Coal—2 ft. 1 in. is represented by

Coal, Sample, No. 10	1	10

The dip here is at 33 degrees to 136 degrees E. of N. At XV is a mudstone with *Cyrena* shells, which forms a reef in the middle

of the stream bed, this reef dips at 50 degrees to 110 degrees east of north; the steep angle of dip being due to local rolling.

Although I have noted all the thicknesses of the various seams in this portion of the Chaung, they do not appear to present any features of interest, and I have omitted them as unnecessary.

Of the seams below those of the main excavations it is now evident that with one exception all are less than 2 ft. thick and that they are usually disintegrated by partings of clay and carbonaceous shale.

Dips.

At XVI there is another abnormal dip of 47 degrees to 140 degrees east of north.

At XIV the dip is to 140 degrees E. of N.

At XX the dip is at 28 degrees to 114 degrees E. of N. This dip is more reliable than the dips at XV and XVI since it is taken from a thick bed of sandstone, while the others are from thin beds in shale, which are very apt to be crumpled and thus deceptive. We have seen that the dip at the Main Excavation No. 1 was at 29 degrees to 141 degrees E. of N. At II, the angle was 34 degrees. I think therefore that the true dip of the main seams must be some figure between 29 and 34 degrees. The dip of the lower seams is more apt to vary owing to rolling than that of the main seams, since the latter are in part protected by the massive sandstone capping them.

The dip in the Yaw River at XXIV is at 39 degrees to 95 degrees E. of N.

We may regard the general dip of the coal-seams in the Letpanhla field as about 30 degrees in the south, and as gradually increasing to about 40 degrees near the Yaw River.

Amount of coal available.

The main seam is over six feet thick for a distance of about half a mile in outcrop, and diminishes between Excavations No. 3 and No. 4 from about 6 ft. to 4 or 4½ ft. For purposes of rough estimation of the quantity of coal available we may suppose that there is an outcrop of a 6 ft. seam half a mile in length and an outcrop of a 5 ft. seam one mile in length.

II. The Tazu Field.

The gently dipping seams running from north to south, west of the village of Tazu, were excavated in four stream sections in

the Shanthe, Kan, Thongwa and Newe Chaungs. I commence by a description of the sections in the most northerly or the Shanthe Chaung.

Excavation in the Shanthe Chaung.—The position of the seams is shown on plate 11, fig. 2.

There are three fairly good seams exposed here, and above these some poor worthless seams. At section No. 1 the lowest of the three seams is exposed and measures as follows:—

		Ft.	In.
Grey clay . . .		5	0
Slightly impure coal .	Sample No. 15 . . .	1	3
Carbonaceous clay .		0	6
Coal		0	5
Clay		0	3
Coal		2	6

Here the dip is at 12 degrees to 95 degrees E. of N.

NOTE.—In this and all other samples, the clay partings are not included in the sample.

At section II the upper of the three seams is exposed, it is:—

	Ft.	In.
Coal, containing two 1" clay partings; Sample 17 .	4	0

The dip here is at 14 degrees to 80 degrees E. of N.

The middle of the three seams is exposed at section III, it is:—

	Ft.	In.
Coal, with one 1" clay parting; Sample 16 . . .	3	6

This is underlain with grey clay and overlain with clay and ochre. The dip is at 12 degrees to 95 degrees E. of N.

Section IV shows a worthless seam, situated above the three good seams above described. It is:—

	Ft.	In.
Coal	1	6
Purple ochreous shale	3	0
Carbonaceous clay with strings of coal	2	0
Coal	0	8
Clay	1	8
Coal	0	6
Clay, over 1 ft., bottom unseen.		

Section V also shows a worthless upper seam, possibly the same as that of section IV.

The measurement is :—

	Ft.	In.
Coal	0	2
Clay	0	4
Coal	1	0
Ochreous clay	3	7
Mixed coal and clay	2	4
Clay	2	5
Coal	0	6
Clay, bottom unseen.		

The dip is here at 13 degrees to 85 degrees E. of N.

There are a few other very thin seams in the stream sections, but they are not worth describing. The differences in dip observations are to be accounted for by (1) experimental error, (2) surface warping of strata, and (3) possibly actual rolling.

Excavation in the Kan Chaung, ¾ mile S. S. W. of Tazu.—The position of the seams is shown on plate 11, fig. 1.

In this section the strata are rolled, so that a small fold is produced. This fold cannot however be called an anticline as it is confined to the soft coal-measures and is merely due to a roll in these soft beds produced by horizontal movement of the sandstones above over the beds below. The normal dip is to E. N. E. at angles varying from 10 to 15 degrees. Three abnormal dips shown on the map, *viz.*, at 30° to 220° E. of N. at section 3 ; at 45° to 290° E. of N. a few yards further to the S. W., and at 30° to 250° at section 4 illustrate the roll of the strata.

The seams are very badly exposed. At section No. 1 the measurements were :—

	Ft.	In.
Ochreous coal	1	1
Clay	0	3
Coal	0	9½
Carbonaceous clay, over 2 ft., bottom unseen.		

At section No. 2 the following :—

	Ft.	In.
Surface soil	3	0
Ochreous clay	2	0
Coal	0	6
Carbonaceous shale	1	0
Coal	1	0
Carbonaceous shale	0	6½
Coal, Sample No. 14	3	0

At section 3 the measurements are :—

		Ft.	In.
Carbonaceous and Ochreous shale		2	8½
Coal	Sample No. 13 (from the three coal seams, omitting clay partings).	0	6
Clay		0	2
Coal		0	10½
Clay		0	11
Coal		1	10½
Gray clay, over 2 ft., bottom unseen.			

I have mentioned above the abnormal dips in this section, which show the roll of the strata. Normal dips are :—

At waterfall — at 15° to 70° E. of N.

N. E. of Section 3 — at 10° to 70° E. of N.

At section 1 — at 15° to 75° E. of N.

Excavations in the Thongwa Chaung.—This section is shown on Plate 12, fig. 2.

As will be seen from the map, the main coal seams are three in number, and are overlain by alternations of sandstone and shale. The measurements of the three main seams are :—

		Ft.	In.
Upper seam—			
Impure coal with gypsum and ochre		0	6
Grey clay		0	4
Coal		0	6
Clay		0	6
Coal, Sample No. 21		2	6
Between the upper and middle seams are seen—			
Clay and shale, about		12	0
The middle main seam measures—			
Coal with one ¼″ parting	Sample No. 20	1	7
Impure coal and carbonaceous shale		0	7
Coal with one 1″ lenticle of clay		2	1½
The seam is poorer below, and shows—			
Grey clay		0	10
Coal with clay partings		0	4½
Coal		0	7
Between the middle and the lower seam are—			
Shales, about		24	0

The lower seam measures as follows:—

	Ft.	In.
Coal, with one ¼″ parting 4″ from top and two 1″ partings at 8″ and 1′ 3″ from top, and one 3½″ parting at 2′ 6″	3	10
Clay	0	5
Impure coal	1	0
Clay	1	2
Impure coal	0	5
Coal	0	7
Shale	0	2
Coal	0	4
Shale	0	2
Coal	0	3
Carbonaceous shale with coal veins	0	9
Impure coal	0	10
Carbonaceous shale with thin veins of coal	1	0
Coal	0	6
Carbonaceous shale	0	9
Coal, bottom unseen. Here the water-level was reached in the pit. It is probable that this last item is thin.		

From the 3 ft. 10 in. seam noted above Sample No. 22 was taken.

Below these main seams other seams are exposed in the stream bed, none are of any importance; the thickest seam being not more than 1½ ft. in thickness.

The dip at the exposures of the main seams is at 17° to 80° E. of N.

Excavations in the Newe Chaung.—A sketch map of this stream is given on Plate 12, fig. 1.

This chaung runs more or less along the strike of the rocks, and there is a thick covering of alluvium; the sections are therefore not nearly so good as those of the Thongwa Chaung.

The main seams are exposed at excavations 1, 2, and 3.

At excavation 1, the sequence is slightly confused by a small fault, but I obtained the following measurements :—

		Ft.	In.
Sandstone		2	0
Coal	Sample No. 18	2	3½
Grey clay		3	0
Coal	Sample No. 19	1	2
Clay		0	1½
Coal		0	2
Clay		0	1½
Coal		0	5
Carbonaceous shale		0	9
Coal		2	4
Carbonaceous clay		0	2
Coal		2	3
Carbonaceous clay		0	5
Coal		0	7

A few feet below this seam a third seam is exposed, which is however quite useless, the thickest bed of coal being 8″. We may therefore speak of two main seams in this area, *viz.*, the upper, from which sample 18 was taken, and the lower, from which sample 19 was taken.

At excavation 2, the upper seam measures :—

	Ft.	In.
Coal	0	2½
Shale	0	3
Coal	0	3
Shale	0	3
Coal	0	6
Ochreous clay	0	8
Coal	2	5

Here the lower seam is not exposed.

At excavation No. 3 the upper, and part of the lower seam is exposed. The measurements are :—

Upper seam—	Ft.	In.
Coal, with stone concretion in seam	1	8½
Clay	0	8
Coal	2	7

The lower seam measures :—

	Ft.	In.
Impure coal	0	2
Clay	0	1
Coal	0	4½
Clay	1	5
Coal	1	8½
Carbonaceous shale	0	11
Coal, bottom unseen, but about	2	0

Other thinner seams, situated below these main seams, are exposed in the chaung, and have been measured; as however they do not appear to be of any economic importance, I omit their dimensions.

Near excavation No. 2, the dip is easterly at about 20°.

The coal-seams have not been traced further south than latitude 21° 15′, which is the southern boundary of sheet 84 K-7. But the seams might be prospected southwards into the adjoining sheet with advantage. The lower seam at excavation 1 measures nearly 7 ft., but is marred by the frequent partings. The upper seam shows improvement as one traces it southwards. At excavation 1 it is 2′ 3½″ in thickness, while at excavation 3, it is 2′ 7″ thick.

Other exposures.—There is a rather bad exposure of the coal in a tributary of the Thongwa Chaung, between it and the Kan Chaung. The main seams do not appear to be exposed on the Yaw River west of Tazu. Halfway between Tazu and Kaingma on the south bank of the river, some poor seams are exposed; these I believe correspond to the lower thinner seams of the Thongwa and Newe Chaungs.

III. Analysis of Coal.

The twenty-two samples of coal for analysis were prepared and analysed under the supervision of Mr. A. K. Banerji, Assistant Curator, Geological Survey, from bulk samples obtained by me in the field from those seams which in the lists of sections given above

I have marked as having been sampled. I give on this page a table showing the results of the analysis.

Analyses of Letpanhla and Tazu Coals.

No. of sample.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	REMARKS.
1	17·67	36·89	33·60	11·84	Ash light brown.
2	17·85	35·65	35·90	10·60	Ash dark brown.
3	17·07	35·39	34·90	12·64	Ash brown.
4	17·38	35·04	37·98	9·60	Ash light brown.
5	18·64	33·46	37·92	9·98	Ash brown
6	15·63	33·37	29·32	21·68	Ash reddish brown.
7	17·30	34·02	36·02	12·66	Ash dark brown.
8	19·42	32·06	33·16	15·36	Ash brown.
9	19·68	34·38	37·38	8·56	Ash reddish brown.
10	18·04	35·20	36·98	9·78	Ash brown.
11	19·22	34·38	37·04	9·36	Ash brown.
12	15·92	37·36	35·22	11·50	Ash dark brown.
13	20·76	33·48	36·20	9·56	Ash brown.
14	21·60	32·54	36·96	8·90	Ash dark brown.
15	21·19	32·51	34·04	12·26	Ash brown.
16	18·98	36·52	34·44	10·06	Ash reddish brown.
17	21·33	34·73	35·22	8·72	Ash brown.
18	20·28	31·74	39·26	8·72	Ash dark brown.
19	18·54	32·12	36·60	12·74	Ash brown.
20	18·02	35·06	39·64	7·28	Ash buff.
21	19·82	31·98	37·54	10·66	Ash light pinkish brown.
22	16·94	33·00	33·18	16·88	Ash brown.

NOTE.—None of the above samples cake.

Table showing the Sulphur contents of eight samples.

No. of Sample.	S (as SO_3)	S (as Sulphide).	Total Sulphur.
1	0·395	1·890	2·285
7	1·298	2·685	3·983
9	0·338	1·800	2·138
11	0·698	1·940	2·638
13	Not separately estimated.		2·778
16	Ditto		4·399
18	Ditto		4·782
21	1·216	4·412	5·628

Table showing the calorific power of eight samples.

No. of Sample.	Calorific Power (determined by bomb calorimeter).
1	4820
7	4517
9	4663
11	4784
13	4499
16	4519
18	4835
21	4510

In order to ascertain how far the high percentage of moisture could be reduced by simple drying, two samples were powdered and air-dried for a week. The test was not perhaps performed under very favourable conditions in the moist air of Calcutta during the rains. Sample 6 after air-drying showed 12·36% of moisture, while sample 17 showed 15·52% of moisture, as against 15·63% and 21·33%, respectively.

IV. The value of the Coal-seams.

In Vol. XXXIII of the Records of the Geological Survey of India, two papers deal with occurrences of coal in Burma, the

fields described being the Lashio coal-field, and the Namma, Man-sang, and Man-se-le fields.[1]

The proximate analyses of these Shan State coals are strikingly similar to those obtained from the Pakokku seams. Both show a remarkably high percentage of moisture, and an excessive proportion of volatile matter as compared with fixed carbon. The ash content is fairly low, but in all other respects the analysis is very disappointing. The Pakokku seams appear on the whole to have a higher percentage of sulphur. The sulphur has been estimated separately according as it occurs as sulphate or as sulphide. The joints of the seams are frequently filled with thin layers of gypsum, and probably all the sulphate occurs either as gypsum or as soluble sulphate. Traces of iron pyrites are often visible.

Owing to these defects, the raw fuel may be assumed to be unsuited for most purposes, except perhaps for dressing tools in forges. The high percentage of sulphur is harmful even for this purpose. It could not compete with coal imported to Upper Burma from India, unless some expensive process of briquetting was resorted to.

The coal can be mined in fairly hard and large lumps, but these rapidly crack to fragments on exposure to air, owing to the loss of moisture.

The roof of the seams is not good, even where it is sandstone, the sandstone is fairly soft. Expensive timbering would be necessary.

The distance from the Letpanhla field to Seikpyu on the Irrawaddy River is about 46 miles over not very hilly country.

Summing up therefore the various defects of these seams, we find :—

(1) The seams are marred by frequent partings, making them expensive to work.

(2) The roof is poor, and would require expensive timbering.

(3) The quality of the coal is very poor owing to the high percentage of moisture, the small amount of fixed carbon, and the presence of excessive sulphur.

[1] The Lashio Coal-field, Northern Shan States, by T. D. LaTouche and R. R. Simpson. (*Rec., Geol. Surv. Ind.*, XXXIII, p. 117.)
The Namma, Man-sang, and Man-se-le Coal-fields, Northern Shan States, Burma, by R. R. Simpson. (*Ibid*, p. 125.)

(4) It is not near any railway and is 46 miles distant from the river.

Against this, it is to be remembered that Bengal coal usually fetches well over Rs. 20 per ton in Upper Burma and the Oil-fields. I may say unhesitatingly that this coal would be useless if situated in a similar position in India, but the high price of Indian coal in Upper Burma makes me unwilling to condemn these fields, although I doubt very much that they are likely to prove of economic value for many years to come.

EXPLANATION OF PLATES.

PLATE 5.—Photograph showing Excavation No. 1 in the Yekyin Chaung.

PLATE 6.—Photograph of the steeply dipping seams opposite Tazu village.

PLATE 7.—The excavations of the three main seams in the Thongwa Chaung.

PLATE 8.—Excavation No. 1 of the main seams in the Newe Chaung.

PLATE 9.—Geological sections across geological map.

PLATE 10.—Geological map of part of Pakokku district, from sheet 84 $\frac{K}{7}$.

PLATE 11.—FIG. 1.—Sketch-map of the Kan Chaung, showing coal-seams.

FIG. 2.—Sketch-map of the Shanthe Chaung, showing coal-seams.

FIG. 3.—A plane table sketch-map of the coal-seams in the Yekyin Chaung and the Yaw River.

PLATE 12.—FIG. 1.—Sketch map of the Newe and Yegyo Chaungs, showing seams.

FIG. 2.—Sketch-map of the Thongwa Chaung, showing seams.

THE MONAZITE SANDS OF TRAVANCORE. BY G. H. TIPPER, M.A., F.G.S., *Officiating Superintendent, Geological Survey of India.* (With Plates 13 to 17.)

INTRODUCTORY.

THE monazite-bearing character of the sands was discovered by Mr. C. W. Schomburg acting on behalf of the London Cosmopolitan Mining Syndicate in the year 1909. In 1909-10 I had an opportunity of examining them and the observations then made are embodied in this paper. I had no opportunity for extended geological work. My results would have been very meagre but for the very interesting specimens which friends in Travancore sent me. I would particularly thank Mr. H. P. Herbert, the then Manager of the Morgan Plumbago Co., and Messrs. E. Masillamani and I. C. Chacko, State Geologists.

Geology of the State.

The only easily accessible papers dealing with the geology of Travancore are by W. King[1] and R. B. Foote.[2] Recently the reports of the State geologists have been published in Trivandrum.

In its broad outlines the geology is very simple, the greater part of the state being constituted of gneissose rocks (charnockites and leptynites). These gneissose rocks form the high hilly and plateau country and also the lower terraced plain, falling gradually to sea-level. In addition to the dyke rocks associated with the charnockites, there are important pegmatite intrusions of much later date which cut the older rocks and may possibly be of the same age as the pegmatites of the Nellore district and other parts of India.

Resting on these Archæan rocks in the immediate neighbourhood of the coast are patches of Upper Tertiary strata (the Warkalli beds) which correspond to the Cuddalore sandstones. At the type

[1] W. King, General Sketch of the Geology of the Travancore State, and the Warkalli beds and reported associated deposits at Quilon in Travancore. *Rec., Geol. Surv. Ind.*, XV, 87 and 93, 1882.

[2] R. B. Foote, The Geology of South Travancore. *Rec., Geol. Surv. Ind.*, XVI, 20, 1883.

locality these beds closely resemble those forming at the present day. Of still later date are the older consolidated blown sands, generally bright red in colour: the estuarine and marine beds described by R. B. Foote from near Cape Comorin.

The coloured and variegated sands[1] of the coast were commented on by both King and Foote.

Distribution of the Monazite.

Monazite is widely distributed over the state. Shows of the mineral can be obtained by washing the sands of many of the rivers and streams and it is present in small quantities in the soil in many localities. Widely distributed though it is, there are only a few places where concentration has given rise to deposits of sufficient richness to be called monazite sands. These places are all in the vicinity of the sea-coast. No concentrates seem to occur in any of the rivers.

Distribution of the Monazite Sands.

From a point on the south-east coast where the state marches with the district of Tinnevelly to Quilon on the west coast five deposits were seen. They may be briefly designated :—

Cape Comorin—Liparum
Muttum--Pudur
Kovilam
Anjengo—Warkalli
Nindikarai (Quilon).

Between these productive spots there are long stretches of barren sand with only faint traces of monazite.

General Character of the Sands.

Although each deposit has certain peculiarities, all present a great many features in common In colour they are usually black due to the presence in predominating quantities of magnetite and ilmenite. They are sometimes red when garnets are in excess. Where there is abundance of quartz or calcite, a grey sand is produced. Excess of monazite gives a yellowish tinge. The other

[1] It may be of interest to note that samples of these sands were collected by W. King and R. B. Foote in 1882, the monazite being identified as zircon.

commonly occurring mineral in the sands is zircon, but practically all the constituent minerals of the Archæan rocks can be found in one or other of the deposits. The zircons often show crystal outlines, while the other minerals are usually rounded. The monazite in particular is always well rounded, and after an examination of many sands I have never seen a specimen which showed any approach to crystal outline. If the relative hardnesses of the commonly associated minerals are compared, it will be seen that monazite is softer than almost all of them. With the exception of quartz and calcite, the densities of the minerals vary from 3 to 5·5.

Physical Character of the Monazite.

In the sands the monazite occurs as small rounded grains (Plate 13, fig. 1) varying from 0·1 to 0·2 millimetres in diameter. Certain deposits are characterised by the constant presence of larger, or smaller, or irregularly shaped, grains. Its colour is best described as resembling amber. Its density is 5·191. Its refractive index is very high. It invariably shows an absorption spectrum in which the didymium lines are well marked. This fact was made use of in the field and in the laboratory for the identification of grains and thin sections. For the field a Browning direct vision spectroscope was used. It is quite easy to separate a few grains on the page of a pocket-book and, in bright sunlight, to get a spectrum at once. For laboratory work a Swift direct vision instrument was first used in connection with a Dick petrological microscope. One of the great advantages of this apparatus is that it is provided with a slit moveable in two directions so that even a small grain will fill the aperture. The spectroscope does not give sufficient dispersion for fine work. More recently a Hilger spectroscope has been used, fitted with a comparison scale. This instrument leaves nothing to be desired.

Other Accumulations containing Monazite.

Sand Dunes.—Considering that these dunes represent material blown from the shore, it is merely a question of the relative sizes of grains of different minerals, assuming that they are all the same shape, as to whether the wind is strong enough to drive them along If the grains are considered to be approximately spherical, the relative volumes of quartz and monazite which can be moved by

the same wind are as 2 : 1. In nature things are not so simple, but it seems probable that a ground wind such as often blows along the coast at Cape Comorin moves rounded grains more readily than flakes or angular fragments. With a high wind such as will raise a sand storm conditions are reversed and angular fragments tend to be more easily raised and blown. At any rate both processes have the same effect, the gradual accumulation of material some distance away from the sea shore. The grinding action of the waves on the minerals of the sands eventually reduces them to such a size that they can be moved along by the wind. The action of the wind is not possible until the sun has dried the top layers of sand. Wet sand seems to be unacted on. Sand dunes are well seen at Cape Comorin, between Muttum and Colachel, at Anjengo and many other localities along the coast. The amount of material in these dunes is considerable, with a very fair percentage of monazite in places near concentrated sands. The difference in size between the lighter minerals such as quartz and calcite and the heavier such as monazite, ilmenite and magnetite could easily be made use of as a means of obtaining a monazite concentrate. It is hardly necessary to point out that the monazite in the dunes is not lost but may by a reversal of conditions be returned to the beach.

The older Dunes.—At Cape Comorin and at Muttum there are older dunes at a higher level than those forming at the present day. They are bright red in colour, due partly to the decomposition of the iron-bearing minerals they contain and partly to the red lateritic dust blown and washed on to them. These dunes are more solid than those of the present day, but have obviously been formed in the same manner. The proportion of monazite they carry seems to be greater. At Cape Comorin they are rapidly coming under cultivation and it is possible to obtain a good concentrate from the irrigation channels bordering each field. At Muttum they are too high above the surrounding country to be of much use. They bear a few palmyra palms. At both places they are being rapidly denuded and the monazite is returning to the sea beach.

On the low cliffs south of the Residency at Cape Comorin there is a very interesting rock. It is a blown sand cemented by calcite to a hard compact material. In some of its upper layers it contains land shells of the genus *Helix*. The main mass of the rock is of the minerals of the beach, generally rounded and including monazite, ilmenite, magnetite, garnet and quartz. In addition there are many

calcareous fragments of organic origin including worn foraminifera. (Plate 13, fig. 2.)

Older Concentrates.—At the base of the Warkalli cliff, at the time of my visit, there was exposed a dark brown ferruginous grit which on closer examination was seen to be composed very largely of the minerals of the present beach, ilmenite, magnetite, garnet and monazite, the latter in some quantity. It was obvious that here was exposed an old beach concentrate and its degradation by wave action was undoubtedly adding to the monazite content of the shore. The Warkalli cliff gives the following generalised section. At the top is a thick band of lateritoid material, succeeded by dark coloured clays with lignite logs and iron pyrites. At the base is the old sea beach. The clay beds are so similar to those forming at the present day in the backwaters that it is impossible to resist the conclusion that this was really their origin. The beds at Warkalli then give evidence of a change from beach conditions to terrestrial and finally of elevation of the deposits so formed to their present position. A similar section is seen near Villenjen. It is possible that similar older concentrates occur at the base of the late Tertiary beds in other places.

I have described these older deposits at some length because I see in them proof that the present-day conditions of concentration on the sea beach are merely a continuation of older conditions. In other words I believe that the monazite has been on the same places for some considerable period of time.

The Rivers in relation to the Monazite deposits.

With one exception, the deposits described are not associated with any large stream and at the present time it is difficult to see how the heavy minerals washed out of the rocks and soil can reach the sea in any quantity, since the rivers empty themselves into inland lagoons and backwaters. These large bodies of water are, in the winter season at least, completely cut off from the sea by bars. The bar may possibly be broken down during the flood season. Even then it seems almost impossible for the current of a river to be strong enough to carry the heavy mineral particles through a lagoon or backwater to the sea. The check on the current at the moment of entry to a larger body of comparatively still water must be so great that the major portion of the burden is dropped. I repeat

that under present circumstances I am unable to believe there is any addition to the heavier minerals of the beach.

If a map of Travancore is examined, it will be seen that the backwaters on the west coast are elongated in a direction parallel to the coast and that their mouths are some distance southward. Where no backwater has been formed, the stream itself has been deflected for some distance towards the south. These facts indicate a strong set of currents running from north to south along the coast and causing a piling up of accumulations in that direction. On the east coast of India the set of the currents is from south to north with a transference of material in that direction.

With the exception of the Anjengo-Warkalli deposit, all the other monazite sands are accumulated to the north of and in amongst the few rocky promontories there are on the west coast. The Cape Comorin mass is caught up in the bays and rocks of the east coast where the set of the current changes. This position of accumulation at first appears anomalous, but it is apparent on consideration that there is the position of greater scour. This is shown by the fact that the profile of the beach is invariably steeper in these places than in the long stretches of unproductive sands which separate them. If this greater scour is conceded, then it follows that a part of the lighter minerals is not deposited but carried on. The effect of this scour must sooner or later cease as the coast becomes more and more uniform in outline. The Nindikarai deposit is being gradually cut off from the concentrating action by the accumulation of a shallow shelving beach of ordinary sand.

The Anjengo-Warkalli deposit is exceptional because it owes its monazite to the denudation of older concentrates in the immediate neighbourhood. It differs from any of the other monazite sands in having a very much higher proportion of the ordinary lighter minerals. It is an ordinary beach sand with an exceptional amount of monazite.

The North-east and South-west Monsoons.

The quiescent period of the north-east monsoon is the time when I believe the actual concentration proceeds at its greatest rate. The action of the currents along the coast is not interrupted by violent winds. The sorting action of the waves is seen at its best. It is during this period that the greater slope of the beach comes into play. The under-tow of the waves gradually pulls the

lighter materials down this slope leaving a concentrate of heavier minerals. The continuation of the process will sort the material still further until only the most dense are left. Near Cape Comorin at low tide the beach is often a glistening mass of rounded grains of yellow monazite. The continual wear and tear of the grains against one another produces the rounded forms so characteristic of these sands. It is possible that the concentrate is continued for some distance below low water level. On the shallower slopes where the unproductive sands are, the selective action of the waves is practically *nil*. The inclined plane is of such low angle that the undersuck is of no effect.

I had no opportunity of seeing the Travancore coast during the south-west monsoon. The following notes deal with probabilities and not with observed facts. At this season the direction of the wind is at right angles to that of the currents. The winds are also more violent than those of the north-east monsoon. The probable effect will be the heaping up of ordinary beach material over the whole coast including the concentrated sands. The concentrated sands are not solid monazite sands, but in section are seen to be composed of concentrated layers of varying thickness separated by layers of unsorted beach material. During a long continued south-west monsoon one may assume the accumulation of so much ordinary sand that the north-east monsoon conditions are unable to cope with more than the upper part. There would then be left an unsorted layer of white sand between two sorted layers of black sand. A thick layer of concentrated sand indicates a long continued period of quiescent conditions.

Origin of the Monazite.

Monazite was first discovered *in situ* by Mr. Herbert in association with the graphite of south Travancore. Later E. Masillamani found it in the younger pegmatites. I saw only one of these occurrences and the following description is based on specimens sent to me. These seem to be of sufficient interest to justify the notes.

There does not seem to be any evidence that the pegmatite intrusions follow any particular direction, but it is probable that they bear some relation to the strike of the gneissose rocks. The intrusive masses occasionally attain a considerable size and as is

common in all pegmatites the minerals tend to segregate. The quartz is sometimes dark brown or reddish in colour with parallel rows of minute inclusions. The felspar is usually decomposed, but seems to be often perthitic, or an intergrowth of two different felspars. Occasionally it forms a micrographic intergrowth with the quartz. In one case it seems to be albite, in which the twin lamellæ fade away before they reach the edge of the crystal. The biotite is of a dark bronze colour and forms conspicuous patches in the rock. The mica is rarely sufficiently well developed to be worth working. Ilmenite when present also forms segregation patches. The monazite has been the first mineral to crystallise but it rarely shows good crystal forms. It has been found in the middle of quartz (Plate 14, fig. 1) and in felspar (Plate 14, fig. 2). In the latter case it is surrounded by an aureole of decomposition and shows multiple twinning. When biotite and ilmenite are present, it seems to associate itself with these minerals (Plate 15, figs. 1 and 2).

The association with graphite is interesting. In the graphite mine at Vellanad, 16 miles north-east of Trivandrum, monazite was found in a rock filling a fault crack. This rock (Plate 16, fig. 1) is composed mainly of brownish crystals of monazite in a matrix of felspar with a little quartz. Thin veins of graphite cut the rock and are later than either of the other minerals. The monazite, yellow in thin sections, is often twinned and encloses small patches of a reddish-yellow mineral which I suggest may be thorium silicate. On its discovery this rock was supposed to be entirely secondary. It is more probably a very rich patch of monazite-bearing pegmatite.

The remaining specimens (Plate 16, fig. 2) show monazite occurring as small veins in masses of graphite. In these the monazite looks different and has a decided greenish tinge. It may be secondary. There does seem, however, to be in Travancore some connection between the pegmatite intrusions and graphite. It is possible to obtain pegmatites showing large pseudo-crystals of graphite which look in every way original. It is, however, impossible to say whether the large vein masses lately mined were due to the intrusions.

The monazite in all the slides is yellow in colour. It has one perfect cleavage parallel to *a* and the twinning plane is parallel to this cleavage. The refractive index by van der Kolk's method is about 1·81. The fluid used was methylene iodide saturated with sulphur. It is optically positive.

Possibility of Occurrence in the gneissose rocks.

After my examination of the monazite sands I came to the conclusion that the mineral must occur as an accessory in the gneissose rocks which occupy so large a part of the state. It seemed to me that in this way only could one account for a mineral so widely spread and so abundant. I have been unable to verify this supposition by an examination of such rocks as I was able to collect; I was unable to trace it either in slides or concentrates. In spite of this negative evidence I do not yet think it proved that monazite does not occur in the gneissose rocks.

Analyses.

The estimation of the thorium content of the monazite was undertaken by Dr. W. A. K. Christie. The material selected was not a sand or a concentrate but was prepared from a specimen composed of monazite, felspar, a litte quartz and graphite. It was first hand-picked and then the separation completed with a heavy liquid (Sonstadt's solution). It was thus possible to prepare monazite free from zircon or any other mineral likely to complicate the analysis.

The method employed was that of Benz (*Zeit. fur angew. Chem.*, XV, 297, 1902). The amount of thorium present as ThO_2 is 6·00 per cent. The silica percentage is 1·55. The molecular ratio ThO_2 : SiO_2 is 1 : 1·13, a result in close agreement with that of Penfield (*Amer. Jour. Sci.*, ser. 3, XXIV. 250, 1882). The thorium is present as a normal silicate.

Two analyses were published in the Bulletin of the Imperial Institute, XI, 103—5, 1911, without any author's name. The amounts of thoria present in two samples of magnetically separated sand were respectively 8·5 per cent. and 10·08 per cent.

Recently S. J. Johnstone (*Jour. Soc. Chem. Ind.*, XXXIII, No. 2, 57, 1914) gives 10·22 per cent. and 8·65 per cent. as the thoria contents of two samples of Travancore monazite, isolated from concentrates.

These results indicate a considerable variation in the amount of thoria present in Travancore monazite.

Distribution of Monazite in other parts of India.

The following notes are based on examination of a number of sands and concentrates brought to Calcutta at different times.

From what has already been written it seems natural to conclude that monazite is most likely to occur in those part of India where charnockites are well developed. The sands have, however, not been collected with sufficient care to settle the question accurately. Of the States and districts bordering on Travancore, sands from Cochin (K. K. Sen-Gupta) did not show any trace, while it occurs widely in the Tinnevelly district (R. B. Foote) in the older dunes, in the dry beds of streams draining eastward from the hills (K. C. Biswas and H. A. Pearson) and in the beach sands where they have undergone slight concentration. It has not been noticed in the sands from Ennore near Madras. It occurs in the streaks of black sand at Waltair (S. W. Kemp) and at Bimlipatam (F. Cross). Similar streaks near the entrance to the Chilka lake in Orissa also contain it (N. Annandale). Sands from the pegmatite districts of Nellore and Bihar and Orissa have so far failed to yield any trace. It occurs sparingly in concentrates from Idar, Central India (C. S. Middlemiss). No monazite was found in washed sands from the Indus river above Attock (C. M. P. Wright). Concentrates obtained during the course of tin dredging in Southern Burma have not shown it. One of these concentrates was extremely interesting as it consisted almost wholly of topaz in small crystals and cleavage flakes (J. R. Booth).[1]

Finally I should like to express my somewhat belated thanks to all those, officials and others, who made my stay in Travancore pleasant, and particularly to the Hon'ble Mr. R. C. C. Carr, then Resident at Trivandrum.

EXPLANATION OF PLATES.

PLATE 13.

FIG. 1.—Monazite grains separated magnetically from sand, Liparum, near Cape Comorin.

FIG. 2.—Blown sand cemented by calcite, Cape Comorin.

[1] In dealing with concentrates, it is often an advantage to be able to obtain a section of some of the constituents. This can be done by embedding them in moderately fluid plaster of Paris. After the plaster has set, it is kept for at least a day in fluid Canada balsam at a fairly high temperature (107°C) to allow the balsam to penetrate thoroughly. A thin section can then be made by rubbing down in the usual way. This method prevents the tearing out of grains as happens if balsam alone is used. It may be pointed out that under this treament the plaster of Paris commences to crystallise in bundles of fine needles.

PLATE 14.

Fig. 1.—Monazite in quartz, from a pegmatite near (west of) Eslandimangalam, Tovala Taluq, South Travancore.

Fig. 2.—Twinned monazite in felspar. Same locality.

PLATE 15.

Fig. 1.—Monazite in biotite, segregation patch in pegmatite. Ashamboo Tea Estate road, South Travancore.

Fig. 2.—Monazite pegmatite, monazite in contact with biotite and ilmenite.

PLATE 16.

Fig. 1.—Monazite felspar rock with a little graphite. Vellanad, 16 miles north-east of Trivandrum.

Fig. 2.—Monazite with graphite. Same locality.

PLATE 17.

Map showing the distribution of the monazite sands, sand dunes, older dunes and Warkalli beds in Travancore.

A LOWER CRETACEOUS FAUNA FROM THE HIMALAYAN GIEUMAL SANDSTONE TOGETHER WITH A DESCRIPTION OF A FEW FOSSILS FROM THE CHIKKIM SERIES, BY DR. ALBRECHT SPITZ (Vienna). TRANSLATED BY E. VREDENBURG, B.L., B.SC., F.G.S., *Superintendent, Geological Survey of India.* (With Plates 18 and 19 and text figures 4-11.)

THE specimens described in the following pages include the collections obtained in Spiti, partly by Stoliczka,[1] partly in more recent times, by Krafft and Hayden; they also include some of Griesbach's collections from Hundes. The specimens were sent to Vienna together with the fauna from the Spiti Shales. I am deeply indebted to the kindness of the late Professor Uhlig for entrusting me with the revision of the present fauna.

Some time previous to the publication of the work in which Stoliczka first established the main outlines of the geology of Spiti, fossils from the Gieumal sandstone had already been described by Blanford[2] and by Salter,[3] but they were united with Jurassic fossils from the Spiti Shales as though belonging to a single palæontological zone. Precise stratigraphical details were first published in 1866[4] by Stoliczka, who described from the Gieumal sandstone a few bivalves of indifferent value for determining the age of the rocks. In consequence of the middle Jurassic age then attributed to the Spiti Shales, the immediately overlying Gieumal sandstone was regarded as upper Jurassic. In later years this error was rectified. Griesbach[5] considered that the deposition of the Gieumal sandstone commenced in upper tithonian times; Oldham[6] spoke of it as "possibly" Cretaceous. As a result of Uhlig's study of the fauna of the Spiti Shales, the Cretaceous age of the Gieumal sandstone was

[1] Stoliczka published a list of the forms which he identified in *Mem., Geol. Surv., India*, Vol. V, 1866, pages 112, *et seq.*
[2] *Journal, Asiatic Society of Bengal*, 1863, p. 124.
[3] Palæontology of Niti, 1865, p. 89.
[4] l.c.
[5] *Mem., Geol. Surv., India.* Vol. XXIII, 1891, p. 80.
[6] Geology of India, 1893, p. 294.

at last definitely established by Diener,[1] and this view has now met with general acceptance.[2] The overlying Chikkim series, consisting of limestones and shales had already been referred to the Cretaceous by Stoliczka on account of the Foraminifera and Rudistæ[3] which it contains.

A.—THE GIEUMAL SANDSTONE.

The specimens communicated to me indicate that in Spiti as well as in Hundes[4] the Gieumal standstone contains three lithological types connected by intermediate gradations, each of which contains a characteristic assemblage of fossils :—

(1) A coarse, porous, calcareous sandstone of an ochreous colour due to its ferruginous contents, with conspicuous grains of white quartz ; fossils are plentiful and relatively well preserved.

(2) A darker-coloured, grey rock, siliceo-calcareous, and always somewhat ferruginous which one might describe as a fine-grained grauwacke-slate ; it contains flakes of muscovite. This variety as well as

(3) a light-grey, non-ferruginous quartzite or quartz-slate, poor in lime, is crowded with badly preserved fossils, mostly casts and impressions.

Since the second type of rock has yielded fossils indicating different chronological horizons, it appears evident that these three divisions are connected with facies and not with stages.

The fossils from each of these divisions will be considered separately.

I. SOFT SANDSTONE.

CARDIUM GIEUMALENSE, n.f., Pl. 18, fig. 5, a, b, c.

A large form with remarkably small, rounded, symmetrically situated umbo, anteriorly to which there is a shallow furrow which becomes more pronounced as the shell grows larger and which extends obliquely (in the direction of the radial striations) downwards. The ornamentation consists of numerous, crowded radial ribs, in the intervals between which finer ribs are regularly intercalated These

[1] *Denkschrift Wiener Akad. d. Wissensch,* 1895, pp. 55, 56.
[2] See Hayden, *Mem , Geol. Surv., India,* Vol. XXXVI, 1904, p. 86.
[3] (l.c.,p. 116.)
[4] See Griesbach, *Mem., Geol Surv.. India,* Vol. XXIII, p. 80.

are crossed by concentric striations of varying degrees of fineness. The shell is strongly convex. Large specimens sometimes exhibit irregularities in the convexity towards the inferior margin together with some waviness of the ribs. The hinge exhibits the normal characters of the genus.

This beautiful species is distinguished from all other Cretaceous species of *Cardium* by its feebly prominent, centrally situated umbo, by its regularly alternating sculpture, and the absence of nodosities. The nearest ally is *Cardium Lundgreni* Vogel from the upper *mucronata*-chalk of Holland distinguished by a larger umbo, different ornamentation and greater breadth. *Cardium Cottaldinum* d'Orb. from the Lower Greensand, as figured by Woods,[1] has the same shape as the Indian fossils, but the ribs are all of equal width.

Cardium Gieumalense is the commonest fossil from the soft sandstone. It also occurs in the quartzite, Lingti river. Stoliczka and Krafft-Hayden collections.

CARDIUM cf. GIEUMALENSE, n.f. Pl. 18, fig. 4.

This form is closely related to the above, from which it is distinguished by its more pointed, less symmetrically situated umbo, and especially by its much feebler convexity.

The related *Cardium semipustulosum* Mull.[2] from the lower Senonian entirely differs in its ornamentation, as is also the case with *Cardium pullatum* Stol.[3] from the "Trichinopoly group."

Numerous specimens. Gieumal. Krafft-Hayden collection.

CARDIUM n. sp. Ind. Pl. 18, fig. 3.

This form is represented only by a single left valve with subcentral, depressed umbo, slightly deflected anteriorly. The outline is orbicular. The rather weathered ornamentation consists of alternately broader and narrower straight ribs. Only one lateral tooth of the hinge is visible. This is also a very distinct form; related species, such as *Cardium scrobiculatum* Stol.[4] from the Trichinopoly group, differ by their more prominent umbo and their ornamentation.

Only one specimen. Gieumal. Krafft-Hayden collection.

[1] Cret. Lamellibr. of England, *Pal. Soc.*, 1908, pl. XXXII, fig. 11.

[2] Holzapfel, Mollusken d. Aachener Kreide, *Palæontogr.* Vol. XXXV, pl. XVIII, figs. 11, 12.

[3] Cretaceous of Southern India, *Palæont. Ind.*, Vol. III, pl. 11, figs. 8-10.

[4] Cretaceous of Southern India, *Palæont. Ind.*, Vol. III, pl. 11, fig. 14.

OSTREA sp.

1866. Ostrea sp. Stoliczka, *Memoirs, Geol. Surv., India,* Vol. V, p. 114.

This shell unfortunately exhibits only its internal characters; the central portion of the specimen is smooth, while coarse folds are developed round its margin. So far as any determination is at all possible, it would seem to be related to the group of *Ostrea Minos* Coquand[1] or to that of *Ostrea Barrandei* Coquand.[2]

Only one specimen. Gieumal. Stoliczka collection.

GRYPHÆA aff. BAYLEI GUER. Pl. 18, figs. 20*a*, *b*, 21.

Choffat-Loriol, Et. Strat. et pal. d'Angola, *Mém. Soc. de phys. et de science. nat. de Genève*, Vol. 30. No. 2, pl. V, figs. 19–21, p. 93.

Two lower valves recall the abovementioned form by their completely rounded spherical umbo and the absence of a lateral lobe, but they differ owing to their narrower shape. They exhibit coarse concentric swellings.

Gryphœa Baylei appears to occur at Angola in the upper Cretaceous. Coquand has illustrated a flat shell which greatly resembles the upper valve of the Indian form, though without any radial striations, and which may be specifically identical.[3]

Gieumal, Krafft-Hayden collection.

All the other remains of Ostreidæ are unfortunately undeterminable (including the one mentioned by Stoliczka[4] as *Gryphœa* sp.).

PECTEN sp. Pl. 18, fig. 22.

The shape closely recalls *Pecten Agassizi* Pictet and Loriol[5]; the ornamentation, however, is different, the Indian fossil exhibits rather widespread, fine radial ribs alternating with still finer ones; traces of ribbing are discernible with the aid of a lens. This kind of ornamentation, which so frequently occurs amongst the Gieumal fossils differentiates the present form from the numerous other Cretaceous

[1] Monographie, pl. 73, figs. 5-9, Neocomian.
[2] op. cit. pl. 12, figs. 1-4 Campanian.
[3] Monographie du Genre Ostrea, 1869, pl. XLVI, figs. 5-9, Cenomanian.
[4] *Mem., Geol. Surv., India*, Vol. V. 1866, p. 114.
[5] Neocomian des Voirons, pl. IX, figs. 2-4 in Mat. pour la Pal. Suisse, III eme serie

Pectinidæ. The casts of *Pecten Agassizi* also exhibit ribs which are not observed in the case of the Indian fossils.

Gieumal. Krafft-Hayden collection.

TELLINA sp. Pl. 18, fig. 19.

Tellina Beushauseni, Muller,[1] is closely related. The Indian form is somewhat more strongly convex anteriorly; the radial ribs are only just indicated posteriorly and are fewer; the angulation enclosing the area has a much steeper downward slope. The anterior margin unfortunately is not preserved. The German fossil occurs in the lower senonian.

Two specimens. Gieumal. Krafft-Hayden collection.

Opis sp., further described with the fauna of the quartzite where it chiefly occurs, has also been found in the soft sandstone.

2. ARGILLACEOUS QUARTZITIC SLATE.

PSEUDOMONOTIS SUPERSTES n.f. Pl. 18, figs. 6, 7.

1863 Avicula echinata ? Blanford, *Journal Asiat. Soc. of Bengal*, 32, page 137.

1866 Avicula echinata Stoliczka, *Mem. Geol. Surv., India*, Vol. V, page 114.

The two valves of this species differ greatly from one another. The right valve is relatively somewhat larger and less convex than the left one. The umbo scarcely projects beyond the straight hinge line. There is a large posterior wing-shaped expansion, scarcely distinct from the posterior margin and a diminutive anterior ear with a deep byssal notch. The anterior margin is rounded. The ornamentation consists exclusively of concentric striations, except for some radial striæ on the wing-like expansion, increasing in distinctness towards the hinge line. The left valve is smaller, more convex, with a much more prominent umbo, with a feebly independent posterior ear, while anteriorly there is no indication of any such feature. The anterior margin is strongly convex. The ornamentation consists of fine radial ribs locally exhibiting a regular alternation of thicker and thinner elements. They carry minute granules caused by the occurrence of concentric striations. It is

[1] *Abhandlungen d.k. preuss, geol. Landesanst*, New Series, part 25, atlas, pl. IX, fig. 8.

particularly worth mentioning that the ornamentation shows no tendency to become effaced towards the anterior and posterior margin. In both valves, the substance of the shell is thin.

This species has a remarkably Jurassic facies, so much so that Stoliczka unhesitatingly referred it to *Avicula echinata* Sow. This group appears generally to have become extinct in Cretaceous times, though it just survived in America. *Meleagrinella* (=*Eumicrotis*= *Pseudomonotis*) *abrupta* Whitfield [1] from the Cretaceous "lower green marls" of New Jersey, recalls many specimens of the right valve; nevertheless the anterior margin extends more prominently anteriorly, while the left valve lacks all traces of radial ornaments. *Avicula pectinata* Sow. in Woods [2] is referred by Woods to the genus *Oxytoma*, indeed the details of the byssal notch of the anterior ear are not in accordance with *Pseudomonotis*. Amongst Jurassic forms, *Pseudomonotis echinata* Sow. and *Pseud. Braamburiensis* Morris and Lycett [3] both differ by their more unsymmetrical shape, and stronger radial sculpture. A closer analogy is exhibited by certain forms from the Malm such as *Avicula Douvillei* Loriol [4], which both in shape and ornamentation closely recalls the Indian species: nevertheless, in the left valve the posterior expansion is more rounded, while in the right valve the anterior margin slopes more steeply from the umbo. Moreover radial ornaments appear to be wanting in the right valve of the Indian fossil. *Pseudomonotis tenuicostata* Grepp.[5] is extraordinarily similar, only slightly more oblique.

This fossil appears to have already been noticed by Blanford (see the synonymy); Stoliczka has also referred to Blanford's previous notice.

This is the commonest fossil in the quartzitic slate. It also occurs in the quartzite. Gieumal; Lingti-river.

Stoliczka and Krafft-Hayden collections.

ARCA (?) sp. , Pl. 18, fig. 17, a, b. c.

This is a small obliquely quadrangular form, with a small anterior and a large posterior wing. The hinge is straight, the umbo rounded. The ornamentation consists of narrow, prominent ribs, often of alter-

[1] Raritan clay and Greensand marls, *Mem., Un. St. Geol. Surv.*, IX, pl. XIV, figs. 11-14.
[2] Cret. Lamellibr. *Pal. Soc.*, 1905, pl. VIII, figs. 8-14.
[3] Mon. Brit. Great Ool. Fossils, pl. XV, figs. 6-7
[4] Form. Jurass. de Boulogne-Surmer, II, pl. XX, figs. 3-6, p. 319.
[5] Loriol, Oxfordien du Jura Lédonien, *Schweizer pal. Abhandlungen*, vol. XXVII, pl. VI, fig. 44.

nating size. The left valve, which alone is preserved, is strongly convex.

Arca Salbieri Coquand[1] is closely related. Nevertheless the present species is more oblique, with a straight hinge; the posterior ear is more distinctly set off, and the umbo less prominent.

Grammatadon securis Leymerie[2] from the Speeton clay, is broader; the more strongly convex umbo also appears to be bordered posteriorly by an angular edge; the specimen illustrated in fig. 15 which agrees better with Leymerie's original is much broader.[3]

Numerous left valves. Chikkim, Gieumal. Krafft-Hayden collection.

CUCULLÆA (?) sp. 1 et 2.

There are two large specimens representing different species, but both unfortunately so badly preserved that they cannot be identified. One of the specimens perhaps corresponds with *Cucullæa Uhligi* described below (p. 219, pl. 19, figs. 7—9).

Chikkim, Krafft-Hayden collection.

UNICARDIUM cf. TUMIDUM BRIART CORNET, Pl. 18, fig. 16.

Unicardium tumidum Briart Cornet, Geinitz, Elbtalgebirge, 1. Unterer Quader, *Palæont.*, Vol. XX, pl. XL, fig. 4 Unterer Pläner.

In the Indian specimens the umbo is situated rather more forward; nevertheless there is a close agreement with regard to the number and shape of the prominent ribs, which are about half the width of the intervening spaces, and the occasional appearance of secondary ribs; the Indian specimens further agree in the gradual widening of the ribs with increasing growth.

Chikkim, Gieumal. Krafft-Hayden collection.

TAPES ROCHEBRUNI ZITTEL. Pl. 18, fig. 15.

Tapes Rochebruni Zittel, Gosaubivalven, *Denkschr. d. k. Ak. d. Wiss. Wien.*, Vol. XXIV, pl. 111, fig. 4.

[1] Aptien de l'Espagne, 1865, pl. XIV, figs. 7, 8, p. 137.
[2] Woods, Cretac. Lamellibr., *Pal. Soc.*, V, 53, pl. VII, fig. 14.
[3] *Mém., Soc. Géol., de France* Vol. V, pl. VII, figs. 6-7.

This small species represented by numerous specimens agrees with the Alpine fossil; the only possible difference consists in the perhaps somewhat coarser concentric furrowing of the European form.

Chikkim, Gieumal. Krafft-Hayden collection.

TELLINA cf. STRIGATA GOLDFUSS, Pl. 18, fig. 18.

Tellina strigata Goldfuss, Pl. 147, fig. 18, see also Holzapfel, Kreide von Aachen, *Palaeont.* Vol. XXXV, pl. XI, figs. 6 -10.

The Indian fossil closely resembles the forms above quoted, though perhaps slightly more slender; the fine radial striations of the Aachen form are not preserved; the latter is from the lower senonian.

A single specimen. Gieumal. Krafft-Hayden collection.

APORRHAIS AFF. DUPINIANA ORB. Pl. 18, fig. 12.

Aporrhais Dupiniana Orb. in Pictet-Campiche, Mat. Pour la Pal. Suisse, 3 eme serie, pl. 92, figs. 1—3.

Numerous casts represent a form closely corresponding with the French fossil, both with regard to the shape of the shell and the presence of a nodose ornamentation, and of two keels on the body-whorl. The wing seems to differ somewhat, reaching higher in the Indian form, and it seems to possess a second deeper lobe which is broken off in the figured specimen. The French fossil is from Valange and Hauterive.

Common, Chikkim, Lingti river. Krafft-Hayden collection.

HOLCOSTEPHANUS (ASTIERIA), (of the group of Atherstoni Sharpe).

The fossil here referred to is a large fragment unfortunately only in the condition of an impression. On the umbilical side it exhibits elongated tubercles which are fairly prominent, especially on the last whorl. From each node there issues a bundle of six or seven sharp, undivided ribs, which after a very slight backward bend follow a straight course forward. The external region is not preserved. The umbilicus must have been rather narrow. So far as can be judged by the only character preserved, namely the ribbing, this form seems

very closely related to the South-African *Holcostephanus Atherstoni* Sharpe[1]. The discussion of this form by Kitchin [2] may be seen.

The form from the valanginian of Mexico described by Burkhardt as *Astieria* cf. *Atherstoni* is also very similar.[2]

Other related forms such as *Holcostephanus Astierianus* in Pictet-Campiche [3] and *Holc. multiplicatus* [4] Roemer differ either on account of the smaller number of ribs, or their dichotomous disposition.

All these forms characterise the lower neocomian and do not reach beyond the hauterivian. Only one form of the group of *Holcostephanus Astieri* constitutes an exception to this rule, having been recorded by Uhlig from the Wernsdorf beds of barremian age.[5]

In the Spiti shales there is a great contrast between the excessive abundance of the sub-genus *Spiticeras* and the scanty development of *Astieria* which is only represented by *Astieria Schenki* Opp.[6] and one species of the group of *Astieria Atherstoni*.

One specimen ? N. of Tootigaag ? (label illegible). Krafft-Hayden collection.

HOPLITES (PARAHOPLITES) sp. Pl. 18, fig. 1*a*, *b*.

A small form with very narrow umbilicus and tall aperture; the siphonal region is slightly flattened. The feebly developed crowded ribs on issuing from the umbilicus first proceed forward, then backward, and finally resume a forward course with which they extend over the siphonal region where they become rather indistinct. In the inner part of the whorl they divide into two or three branches, the most conspicuous of which seems to be the posterior one. On nearing both the umbilicus and the siphonal region they show a slight tendency to form swellings.

A very closely related form is *Parahoplites Nolani* Seunes[7] which differs by the greater width of the umbilicus. Moreover Jacob also describes a *Parahoplites* cf. *Nolani*,[8] which exactly agrees with the

[1] *Transact. Geol. Soc.*, London, 2nd series, Vol. VII, pl. XXIII, fig. 15.
The Invertebrate fauna of the Uitenhage Series, *Ann. S. Afr. Mus.* 1908, p. 187.

[2] Fauna jurassique de Mazapil, *Boll. Inst. Geol. de Mexico*, 23, 1906, Pl. XL, fig. 23.

[3] Mat. pour. la. Pal. Suisse, 2 eme, serie, pl. XLIII.

[4] Norddeutsche Kreide, Vol. XIII; see also Neumayer-Uhlig, Hilsammoniten, *Palæont*, Vol. XXVII, pl. XXXIII.

[5] Cephalopodenfauna d. Wernsdorfer Sch. *Denkschr. d. k. Ak. d. Wissensch. Wien*, Vol. XLVI, 1883, p. 116.

[6] See Uhlig, *Pal. Ind.*, *Ser.*, XV, Vol. IV, pl. VIII, fig. 2.

[7] *Bull Soc. Géol. de France*, 1887, (III) Vol. V., p. 564, pl. XIII, fig. 4, *a*, *b*, see also Jacob, *Bull. Soc. Géol. de France*, 1905 (IV), Vol. V, p. 408.

[8] Op. cit. p. 409, pl. XIII, fig. 1.

type except for its somewhat greater compression, narrower umbilicus and more quadrangular section. This form therefore approaches the Indian fossil very closely. Unfortunately it is not possible definitely to unite the two forms by a comparison with the illustrations, especially as the specimens studied by Jacob are badly preserved. This form is from Clansayes at the junction of the aptian and Gault.

Another related form is *Hoplites jodariensis* Douvillé.[1] The ornamentation, however is more prominent, and the branching of the ribs takes place, higher up along the flanks. This is a hauterivian form.

Other analogous forms of *Holcodiscus*, such as *Holcodiscus menglonensis* Sayn-Lory, differ by their more rounded siphonal[2] margin, while the ribs lack the tendency to develop nodes at the junction of the flanks with the siphonal region, upon which, moreover, they do not tend to disappear.

One specimen. Lingti river. Krafft-Hayden collection.

HOPLITES (STOLICZKAIA) cf. DISPAR ORB. Pl. 18, fig. 2.

This form is represented by a fragment of a whorl with a very characteristic ornamentation consisting of broad, slightly sigmoidal flexuous ribs which become much broader towards the siphonal region over which they apparently extend without any interruption. Intercalated between them are secondary ribs, originating at about half the height of the whorls, and likewise apparently extending over the siphonal region.

This fossil agrees so perfectly with certain stages of growth of *Stoliczkaia dispar* Orb.[3] that only in consequence of its poor state of preservation do I refrain from positive identification.

D'Orbigny's typical *Ammonites dispar*[4] includes the variety with straight ribs in the adult stage, corresponding with Stoliczka's illustration.[5]

Nevertheless according to Pictet's description, there is every gradation between this variety and the forms with flexuous ribs.[6] The

[1] Esquisses geol. des Préalp. subbétiques, Thèses prés. à la fac. des. sciences de Paris, 1906, pl. XIII, figs. 7, 7*a*, p. 207.

[2] Sur la constitution du syst. crétacé aux environs de Châtillon en Diois, p. 23, fig. 6.

[3] Pictet-Campiche, Ste Croix, Mat. pour la. Pal. Suisse, 11 ème série, pl. XXXVIII, fig. 4.

[4] *Pal. française*, pl. XLV, figs. 1, 2.

[5] *Palæont. Ind.*, Cretaceous of Southern India, Vol. I, pl. XLV.

[6] Ste. Croix, II ème série, pp. 265 ff.

variety with flexuous ribs has also usually been figured under the name *dispar*, a specimen in the collection[1] of the Palæontological Institute of the University of Vienna indicates also the presence of this variety in the "Ootatoor group."

One specimen. Lingti river. Krafft-Hayden collection.

3. QUARTZITE.

AVICULA ? aff. SANCTÆ CRUCIS PICTET-CAMPICHE. Pl. 18, fig. 8.

Avicula ? Sanctæ Crucis Pictet-Campiche, Mat. pour la Pal. Suisse, V. eme ser., pl. 152, fig. 5.

The available specimens are, unfortunately, badly preserved in the umbonal region; nevertheless, in their shape, their feeble convexity, in the slightly confused, feeble radial ribbing, with its tendency to disappear laterally, they thoroughly agree with the French form (Valange).

Common. Gieumal. Krafft-Hayden collection.

LIMA aff. ARZIERENSIS Loriol. Pl. 18, figs. 13*a*, *b*, 14.

Lima Arzierensis Loriol. Valangien d'Arzier, Mat. pour la Pal. Suisse, IV eme serie, pl. III, figs. 9, 10.

This fossil agrees thoroughly with the French form with respect to the coarse, granulated radial ribs, the gradual weakening of the ornamentation towards the sides and the pronounced convexity of the shell. At the same time the Indian fossil is more symmetrical, with alternating radial ornamentation, and a smooth wing.

Common. Gieumal. Krafft-Hayden collection.

OPIS sp., pl. 19, figs. 1*a*, *b*, *c*, *d*, 2.

1866, Opis sp. Stoliczka, North-Western Himalaya, *Mem. Geol. Surv., Ind.*, Vol. V, p. 116.

There are abundant remains of a large *Opis*, which unfortunately are all in the condition of internal casts, so that an exact identification is not possible.

[1] See Bayle et Zeiller, Explication de le carte géol. de France, pl. XLVI, fig. 2, from the "lower chalk" Choffat and Loriol, Mat. pour l'étude stratigr. et. pal. d'Angola, *Mém. de la Soc. de Phys. et d'hist. nat. de Genève*, Vol. XXX, No. 2, 1888, pl. II, figs. 5-9, Gault or vraconnian.

The casts indicate a form with tall though somewhat thick umbo, slightly deflected forward, and curved inward. On the posterior margin of the umbo, an angulation extends from the apex towards the posterior margin, enclosing an area on its inner side. In front of the angulation, there is a more or less pronounced shallow depression; the anterior region only shows a keel bordered on either side by broad shallow depressions. Under the umbones is a small prominence directed inwards in which their outline is again repeated.

The lower margin is rounded, the anterior margin greatly produced, while the posterior margin slopes away from the umbo rather straight and steep.

So far as it is possible to compare casts, the nearest relative to this fossil is *Opis bicornis* Geinitz[1] from the Lower Pläner (cenomanian), the correspondence between the two forms is very thorough, though the Indian fossil differs by its thicker and shorter umbo, the presence of a projection beneath the umbo, and the steep declivity of the posterior margin towards the lower margin, while in the European form the posterior margin projects considerably.

Common. Gieumal. Also one specimen from the coarse sandstone of Chikkim.

Stoliczka collection.

LIMA SP.

1866 Lima sp. Stoliczka, *Memoirs*, *Geol. Surv.*, *India*, Vol. V, p. 115.

A large concentrically furrowed *Lima*, not otherwise determinable.

Gieumal. Stoliczka collection.

CARDIUM SP.

A fragment of a tall, slender *Cardium* with well-marked radial ribs.

Gieumal. Stoliczka collection.

CARDIUM n. sp. indet. Pl. 18, fig. 11*a*, *b*.

The right valve is very slender and tall, with rounded umbo feebly bent forward. The posterior margin is not sinuated, and extends

[1] Elbtalgebirge, *Palæontographica*, Vol. XX, 1st part, pl. 2, figs. 1-3.

with regular curvature from the umbo, while the anterior margin exhibits a short rounded wing. The ornamentation consists of very fine, crowded striations, for the most part arranged alternately; they combine with the lines of growth to give rise to small granules; this ornamentation extends regularly over the entire surface of the valve (unfortunately, while developing the specimen, the middle portion of the shell got lost).

This form belongs to the group of *Cardium productum* Sow.[1] Both this species as well as *Cardium Reussi* Zittel[2] are more symmetrical, with a sinuated posterior margin, and a somewhat more extended anterior ear; moreover they lack the alternating character of the ornamentation. The same differences distinguish *Cardium cenomanense* Orb.[3]

Only one specimen Gieumal. Stoliczka collection.

PANOPÆA cf. ARCUATA ORB. Pl. 18, fig. 10.

Panopæa arcuata Orb., *Pal franc.* pl. 355, figs. 3, 4. Neocomian=P. rostrata Math.

1866. Anatina n. sp. Stoliczka, North-Western Himalaya, *Mem. Geol. Surv., India*, Vol. V, p. 116.

Unfortunately only one well preserved specimens is available. It is a very elongated depressed left valve. The umbo is situated rather far forward and is rounded. The anterior region is relatively elongated and elegantly rounded, the posterior region greatly extended and gradually tapering. The surface is ornamented with irregular concentric furrows.

The French species is larger than the specimen above described; yet amongst the Indian material, there are fragments indicating considerable dimensions. The only distinction lies in the umbonal region, which in the European species is somewhat broader while the anterior region is rather shorter.

Gieumal. Stoliczka collection.

Cardium gieumalense and *Pseudomonotis superstes*, both of which are very abundant in the sandstone and quartzitic slate, also occur sparingly in the quartzite.

[1] Zittel, Gosaubivalven, *Denkschr. d. k. Akad. d. Wissensch, Wien*, vol. XXIV, p. vi, fig. 1.

[2] loc. cit., fig. 3.

[3] Geinitz, Elbtalgebirge, *Palæontographica*, Vol. XX, 1st part, pl. L, fig. 9, from the lower Quader (cenomanian).

Before concluding these descriptions, it is necessary to mention two more forms occurring in a different rock, a dark arenaceous limestone crowded with shells; it is very similar to the strata of Dogger age from Spiti and Hundes and the question arises as to whether some confusion may not have happened in the labels.

CORBIS ? MONTANA n.f. pl. 18, fig. 9.

The hinge is unfortunately concealed so that the genus cannot be precisely determined.

The shell is symmetrical, with a strongly curved umbo, ornamented with coarse, broad, transverse ripples, some of which are repeatedly subdivided. It is distinguished from all analogous Jurassic or Cretaceous forms owing to the greatest breadth being situated close to the lower margin.

One specimen. Chikkim. Krafft-Hayden collection.

AVICULA SP.

The specimen which is unfortunately incomplete, indicates an oblique form with coarse, partly alternating radial ribs. It apparently belongs to the group of *A.* (*Oxytoma*) *inæquivalvis*, which extends with but slight changes throughout the Jurassic and Cretaceous.

Stoliczka collection. Locality unknown.

The following list includes all the species determined :—

1. From the calcareous sandstone.

   Cardium gieumalense n.f. (very common).
   Cardium cf. *gieumalense*.
   Cardium n.sp. ind.
   Ostrea sp.
   Gryphæa aff. *Gaylei* Guer.
   Pecten sp.
   Tellina sp.
   Opis sp. (rare).

2. From the argillaceous quartzitic slate :

   Pseudomonotis superstes n.f. (very common).
   Arca ? sp.
   Cucullæa ? sp.
   Unicardium cf. *tumidum* Briart-Corn.
   Tapes Rochebruni Zitt.

Tellina cf. *strigata* Gf.
Aporrhais aff. *Dupiniana* Orb.
Holcostephanus (*Astieria*) aff. *Atherstoni* Sharpe.
Hoplites (*Parahoplites*) sp.
Hoplites (*Stoliczkaia*) cf. *dispar* Orb.

3. From the grey quartzite.

Pseudomonotis superstes n.f. (rare).
Avicula ? aff. *Sanctæ Crucis* Pict.-Camp.
Lima aff. *Arzierensis Lor.*
Opis sp. (common).
Lima sp.
Cardium sp.
Cardium n.sp. ind.
Cardium gieumalense n.f. (rare).
Panopæa cf. *arcuata* Orb.

4. From the dark "lumachell" (? Dogger).

Corbis montana n.f.
Avicula sp.

Amongst Stoliczka's [1] types the following do not occur in the material examined.

MYTILUS MYTILOIDEA BLANF. (previously described by Blandford.[2] From the illustrations it is not possible to ascertain whether this may not represent some other genus for instance *Inoceramus.*

PECTEN BIFRONS SALTER figured in Salter's Palæontology of Niti [3] *Amusium demissum* Bean (an identification which, in any case, would need revising, especially as Stoliczka took the Gieumal sandstone for Jurassic.

ANATINA SPITIENSIS STOL.

Blanford has also figured a *Cyprina* ? *trigonalis* [4] which together with "*Avicula echinata*" our *Pseudomonotis superstes*, occurs abundantly in the Gieumal sandstone. Blanford's fig. 4 represents an undeterminable cast, and the same is the case with fig. 5, which, however, suggests the impression of a *Trigonia.* This form does not occur amongst our material.

[1] See *Mem., Geol. Surv., India*, Vol. V, 1866, p. 114.
[2] *Journ. Asiatic Soc. of Bengal*, 1863, pl. IV, fig. 8.
[3] Salter's Palæontology of Niti, pl. XXII, fig. 5 *non* figs. 6, 7; cf. Stoliczka, p. 74; the latter are jurassic.
[4] *Journ. Asiatic Soc. of Bengal*, 1863, p. 135, pl. IV, figs. 4, 5.

In attempting to estimate the stratigraphical value of this small fauna, we may first take into account the age of the underlying Spiti shales. In this respect the late Professor Uhlig had kindly communicated to me the following particulars.

" The fossils from the Spiti shales have not hitherto been collected strictly in accordance with their stratigraphical horizons. A subdivision of the Spiti shales into three zones was first established by L. C. Griesbach and C. Diener, who observed that the newest zone, the " Lochambel-Beds " gradually merges into the overlying Gieumal sandstone. These Lochambel beds cannot therefore strictly represent a single palæontological unit, but must include a succession of palæontological horizons. The first result of a preliminary examination of this fauna, published in 1895,[1] was to the effect that it belongs to the Berrias stage, but also exhibits affinities to the upper tithonian on the one hand and on the other hand, to the valanginian. Further study has revealed the presence of a considerable number of forms which in Europe are essentially characteristic of the lower neocomian or valanginian, particularly amongst the *Hoplites*, for instance *Hoplites* (*Kilianella*) *pexiptychus* Uhl., *Hoplites* (*Neocomites*) *neocomiensis* d'Orb., *Hoplites* (*Thurmannia*) *Thurmanni*. They are accompanied by other forms of *Hoplites*, which must be regarded as new species, but which bear the closest relation to lower neocomian types. Some of the ammonites from the Lochambel beds, such as *Acanthodiscus subradiatus* or *Simbirskites* aff. *discofalcatus* Lah. are even related to middle neocomian or hauterivian forms.

In view of the remarkable development of valanginian *Hoplites* it seems improbable that we should be merely dealing with forerunners of the true valanginian fauna, such as might have developed in India earlier than in Europe, at a time corresponding therefore with the Berrias stage. From the evidence derived from our studies of the European faunæ it appears far more likely that the Lochambel beds also include the valanginian horizon. We cannot even exclude the possibility of the presence, within the Lochambel beds, of the lowest zones of the middle neocomian, though the probabilities are not in favour of this view. The presence of the higher horizons of the middle neocomian is not supported by any palæontological evidence.

[1]Geolog. Expedition in den Z. Himalaya, *Denkschr. d.k. Akad. d. Wissensch, Wien., math. nat. Classe,* LXII, 1895, p. 55.

Since the overlying Gieumal sandstone passes by interstratification into the Lochambel beds, the geological age of its lower limit is fairly accurately determinable. The base of the Gieumal sandstone cannot be older than upper valanginian nor newer than middle hauterivian."

The character of the fauna above described agrees perfectly with this conclusion. The bivalves are not of much value for chronological determinations. Amongst the ammonites, the *Astieria* is decidedly neocomian: related forms in Europe are of wide occurrence in the valanginian and hauterivian, while stray examples even reach the barremian. The valanginian is excluded as a result of Uhlig's researches. The fossil therefore indicates a middle or upper neocomian horizon. Our *Parahoplites* has its closest ally in Europe at the junction of the aptian and Gault, and indicates therefore a middle Cretaceous age; *Stoliczkia dispar* in Europe, characterises the Gault and cenomanian, while in India it occurs in the "Ootatoor group" (cenomanian).

If therefore we apply the results of European investigations to Himalayan geology, we are led to look upon the Gieumal sandstone as an assemblage of beds ranging from middle neocomian up to the base, at least, of the upper Cretaceous. The overlying Chikkim series, whose conformity with the Gieumal sandstone has been positively asserted[1], must therefore include representatives of the upper Cretaceous.

From the point of view of geographical distribution, the occurrence of an *Astieria* of the group of *A. Atherstoni* is interesting; this is a characteristic form of the Uitenhage formation, while, according to information kindly communicated to me by Herr R. Folgner, it also occurs at the junction of the valanginian and hauterivian in the Salt Range (Chichali Pass). A related form also occurs in the Spiti shales. This may perhaps indicate free communication between the neocomian seas of the Himalayan region, and the oceans further to the south-west;[2] very closely related forms occur, indeed, in Europe [3].

It is strange, therefore, that the bivalve-fauna of the Himalaya should not contain any of the forms met with in the Uitenhage

[1] Griesbach, *Mem. Geol. Surv., India*, Vol XXIII, p. 81.

[2] For a full discussion of this question, see Kitchin, Uitenhage formation, *Ann. S. Afr. Mus.* 1908, p. 51.

[3] See Kitchin *loc. cit.*

formation. The Gieumal sandstone contains no trace, apart from Blanford's doubtful *Trigonia*, of the *Trigoniæ* which occur so widely not only in South-Africa but also in German East-Africa, in the "Oomia group" of Kachh, as well as in Hazara (Afghanistan); in spite of the imcompleteness of the Gieumal fauna collections, this absence can scarcely be accidental.

In general the preservation of the bivalves is too unsatisfactory to permit any weighty conclusions, in consequence of the resulting uncertainty of the identifications. The local character of a portion of the fauna also detracts from the value of the evidence. For instance *Cardium Gieumalense* and *Corbis ? montana* are striking examples of local types. Likewise *Pseudomonotis superstes* exhibits strong Jurassic affinities. The Himalayan Dogger has yielded two undescribed species of *Pseudomonotis* belonging to this same type. The Spiti shales, nevertheless, do not yield any connecting links, all the Pseudomonotidæ from that formation being smooth. The commencement of the deposition of clastic sediments at the upper limit of the spiti shales corresponds with a radical change in the fauna. The numerous ammonites dwindle away, there is a complete disappearance of *Astarte, Inoceramus, Ancella, Nucula,* of all those genera of bivalves, therefore, that communicate to the Spiti shales fauna its special character, while *Cardium, Ostrea* and *Pseudomonotis* take their place. Both the lithology and fauna of the Gieumal sandstone indicate a shallowing of the sea (according to Walter, all the species of *Cardium*, with few exceptions, live at feeble depths). This shallow-water fauna, unrelated to that of the Spiti shales, *must therefore have migrated from* some other region; this region also became the last refuge of *Pseudomonotis*, a genus which elsewhere appears to have been extinct in neocomian times. In this connection it is worth considering the close connection between this genus and the upper Cretaceous *Meleagrinella* (=*Eumicrotis*) from North America.

B. CHIKKIM LIMESTONE FROM SPITI.[1]

The material at my disposal includes a grey, arenaceous marl, weathering brown, crowded with the remains of foraminifera. The forms described below are of relatively large dimensions, and only need a feeble magnification for their study. They are not of any

[1] See Stoliczka, *Mem. Geol. Surv., India,* Vol. V. 1866, p. 116.

stratigraphical value, but may be of assistance locally in the case of any further geological examination of this series.

NODOSARIA sp. 1.

The chambers are large, rounded, smooth, separated by a deep slit with a rapid ratio of increase; five chambers are preserved, the initial and last one being absent; nevertheless the general appearance indicates that the total number was small and that the form should be compared with those of the group of *Nodosaria soluta* Reuss[1].

Chikkim. Krafft-Hayden collection.

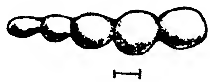

FIG 4.

NODOSARIA sp. 2.

The chambers are elongate, oval, smooth, with oblique partitions; the first and last chamber are missing. These characters recall the group of *N. filiformis* Orb.[2]

Chikkim. Krafft-Hayden collection.

FIG. 5.

[1] Brady, Challenger Report, pl. 62, figs. 13-16.
[2] Brady, Challenger Report, pl. 63, figs. 3-6.

NODOSARIA sp. 3.

1866. *Nodosaria* sp. Stoliczka, North-Western Himalaya, *Mem. Geol. Surv., India,* V, p. 118.

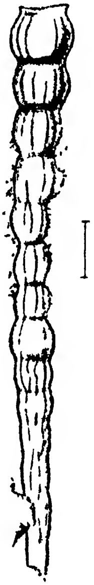

FIG. 6.

A very large *Nodosaria* with rounded-oval, occasionally somewhat elongate, longitudinally striated chambers, belongs to the group of *N. Zippei* Reuss.[1] as had already been correctly indicated by Stoliczka.

Chikkim. Stoliczka collection.

NODOSARIA 4.

1866. Dentalina cf. annulata Stoliczka, *Mem. Geol. Surv., India,* V, p. 118.

FIG. 7.

[1] Bohmische Kreide, pl. VIII, figs. 1-2.

A somewhat curved form (*Dentalina*), the convex side of which is shown in the illustration. It has rounded, somewhat compressed chambers. The last chambers are missing. The first chamber seems to be drawn out to a point. In the neighbourhood of the embryonic chamber the specimen is not well preserved and it is not quite certain whether, here, the chambers do not lose their rounded outline. This form recalls *Nod. annulata* Reuss as illustrated by Alth[1] from the upper Cretaceous, in which, however, the first chambers have distinctly flattened surfaces.

Chikkim. Stoliczka collection.

CRISTELLARIA sp. 1.

A large form with the earlier chambers spirally coiled, and followed by about three detailed chambers, the septa of which are perpendicular to the direction of elongation of the detached portion, the chambers of which no longer reach the coiled portion. The outer margin is keeled. The forms nearest related are *Cristellaria lituiformis* Reuss[2] and *Cristellaria lituola* Reuss.[3]

Chikkim. Krafft-Hayden collection.

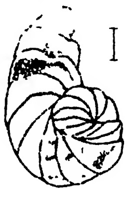

FIG. 8.

CRISTELLARIA sp. 2.

1866. Haplophragmium sp. Stoliczka *Mem. Geol. Surv., India*, Vol. V, p. 118.

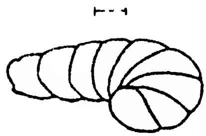

FIG. 9.

[1] Geogn.-palæntol. Beschreibung der Umgebung von Lemberg, *Haidingers naturwissenschaftliche abhandlungen*, *Wien*, III, pl. XIII, fig. 29.

[2] Zur Kenntnis der tertiaren Foraminiferenfauna, *Sitzungsberichte der Wiener Akad. d. Wissensch*, Vol. XLIII, 1st part, pl. IV, fig. 50.

[3] Bohmische Kreide, pl. XXIV, fig. 47, p. 109.

This form closely resembles the one previously described but has a larger number of detached chambers (five). Closely related is the tertiary *Cr. rhomboidea* Czjzek.[1]

Chikkim. Krafft-Hayden and Stoliczka collections.

CRISTELLARIA sp. 3.

1866. Rotalia sp. Stoliczka, North-Western Himalaya, *Mem. Geol. Surv., India,* Vol. V, p. 118.

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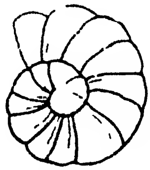

FIG. 10.

A spirally coiled form with strongly projecting, slightly curved broad septa and numerous chambers. *Cristellaria* (*Robulina*) *pterodiscoidea*[2] Gumbel resembles this form with respect to the structure of the septa, while *Cristellaria Kunkeri* Reuss[3] has the same outline with a similar rapid increase of the height of the whorls.

Chikkim. Stoliczka and Krafft-Hayden collections.

TEXTULARIA sp.

1866. Textularia 2 sp. Stoliczka. *Mem. Geol. Surv., India,* Vol. V, p. 118.

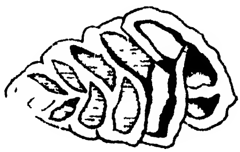

FIG. 11.

Sections of two *Textularia* one of which was compared by Stoliczka with *T. anceps* Reuss. One of these specimens is undeterminable,

[1] *Haidingers naturw. Abhandlungen, Wien,* Vol. II, pl. XII, figs. 21-23.
[2] Gumbel, *Abhandlungen d. bayr. Akad. d. Wiss.,* Vol. X, pl. 1, fig. 72.
[3] Foram. d. norddeutschen Hils und Gault, *Sitzungsberichte d. Wiener Akad. d. Wissensch.,* Vol. XLVI, 1st part, p. VIII, fig. 6.

while the other (text figure 11) by its laterally expanded chambers, recalls *T. Baudouiniana* Orb.[1]

Chikkim. Krafft-Hayden and Stoliczka collections.

These sections exhibit, besides remains of *Textularia, Dentalina* and other forms, a great abundance of *Globigerina* chambers.

One of the fragments referred by Stoliczka to the Rudistæ is amongst the material handed over to me; its fibrous structure plainly shows it to be a fragment of *Inoceramus.*

The only missing specimens out of the material described by Stoliczka[2] are a *Nodosaria* (said to resemble *N. intercostata* Reuss) and a *Cristellaria sp.*

Besides the above described forms, I have had access to Griesbach's collections from the so-called Chikkim limestone of Hundes[3]; the matrix is a light-grey to white limestone crowded with shell fragments. The rock rests upon the Gieumal sandstone and was therefore referred by Griesbach to Stoliczka's Chikkim series of Spiti, from which it entirely differs lithologically. It is, therefore, not quite certain whether it may not represent a Jurassic rock from the "exotic series". The presence of small canaliculate belemnites related to *B. Gerardi* lends support to this conclusion, though also occurring in the neocomian of the Salt-Range (see the special description). *Astarte hundesiana* has its nearest analogue in the group of *A. striato-costata* from the Jurassic of Europe, while *Cucullæa leionota* resembles *Cucullæa Uhligi* from the Himalayan Dogger. Further discoveries will perhaps settle the exact age of these rocks.

CUCULLÆA UHLIGI n. sp. pl. 19, figs. 8, 9*a*, *b*, 10*a*, *b*.

A large form with rounded, quadrate outline. The umbo is central, rounded, and strongly convex. Posteriorly to it is an area marked off from the remainder of the shell by an angulation whose sharpness decreases towards the posterior margin. The hinge line is slightly curved; the anterior and posterior margins converge towards it and are connected with it without any sudden angle. The ligament area is tall, ornamented with broad oblique ledges, separated by fine furrows. The shell is moderately convex. The hinge is not visible.

[1] Egger, Foraminiferen aus den oberen Kreidemergeln der oberbayrischen Alpen, *Abhandlungen bayr. Akademie d. Wissensch*, Vol. XXI, pl. II, fig. 10.
[2] See *Mem. Geol. Surv., India*, 1866, Vol. V, p. 117.
[3] Griesbach, *Mem. Geol. Surv., India*, 1891, Vol. XXIII, p. 80.

In addition to the lines of growth, the surface carries coarse, ill-defined, irregular concentric swellings, which increase in number and strength with increasing growth. Well-preserved specimens also show fine, alternating, radial striations, especially noticeable towards the margin.

This beautiful species does not seem to be closely related to any Cretaceous fossils. In India there are certain forms such as *Trigonarca Brahminica* Forbes[1] from the "Arrialoor group" and *Trigonarca gamana* Forb.[2] from the "Ootatoor group," which are not unlike in shape, but are nevertheless distinguished by the convergence of the upper and lower margins, which are parallel in the Tibetan form; the species first named also differs in the ornamentation of the ligament area.

Arca ligeriensis Orb[3] from the turonian differs by its elongate, rectilinear, lower margin, its greater convexity, and the absence of radial ornamentation; nevertheless it would seem to be one of the closest related forms (provided, of course, that the hinge of the present form should be similar and should correspond with that of *Arca.*) *Cucullæa brevis* Gerhardt [4] from the aptian, differs owing to the rectilinear course of the lower margin, the more oblique direction of the angulation, which limits the area and which remains distinct in the later stages of growth, and owing also to the absence of radial striations.

This form also seems to be present in the Gieumal sandstone.

Far closer related than any of the Cretaceous *Cucullæa* is a form from the Dogger of Spiti and Hundes, *Cucullæa leionota* Salter.[5] Its umbo is situated more anteriorly and is larger. The Spiti shales have not yielded any connecting links, it is advisable, therefore, to keep both forms separate.

Common. East of Laptel E. G. Hundes.

ASTARTE (VEL ERIPHYLA ?) HUNDESIANA n.sp., pl. 19, figs. 3 : 7.

Triangular, rounded, with pointed umbo, sub-centrally situated; anterior margin concave, posterior and lower margins well rounded,

[1] Stoliczka, Cretaceous fauna of Southern India, *Pal. Ind.*, Vol. III, pl. XVIII, fig. 13, pl. XX, figs. 1, 3.
[2] *Op. cit.*, pl. L, fig. 7.
[3] *Pal. Franc.*, pl. 319.
[4] Steinmanns Beitragen zur Geologie, Pal. Su lamerikas, *Neues Jahrbuch fur Mineralogie*, Vol. XI, pl. V, fig. 4.
[5] Pal. of Niti., pl. XXIII, fig. 4.

convexity moderate. Anteriorly to the umbo is an obliquely sloping sunken lunula.

The ornamentation is very characteristic; in the earlier stages of growth, besides the lines of growth, it consists of fairly well defined, coarse, concentric swellings, about twice the width of the intervening furrows. With increasing growth the concentric swellings become much broader and irregular, they become much less distinct, and finally less conspicuous than the lines of growth; perfectly identical changes are observed during the development of *Astarte obovata* Sow.[1]

The hinge in the right valve includes two cardinal teeth, of which the posterior one is large and thick. Unfortunately it is impossible to ascertain the presence or absence of lateral teeth, so that the generic reference, whether to *Astarte* or *Eriphyla*, must remain uncertain. The external ligament was supported by a fulcrum.

The shape is very variable. In addition to the type in which the height and breadth are about equal, there are individuals in which the breadth greatly exceeds the height. The inner margin is finely crenulated throughout.

The alteration in the character of the ornamentation during the growth of the individual distinguishes this form from all other Cretaceous species; this is the case, first of all with *Eriphyla Stuhlmanni* Muller from the neocomian of Ntandi,[2] which, in its earlier stages, thoroughly agrees in shape with the typical form of the Tibetan species. When full-grown, both forms are, however, totally different.

The broader variety of our species is very similar in shape to *Astarte Beaumonti* Leym.[3] from the spatangoid-limestone of the hauterivian in the Paris basin, in which, however, the ornamentation becomes completely obsolete, a character particularly emphasised by d'Orbigny in his descriptive text.

Other forms externally similar such as *Cytherea libanotica* Noetling[4] with absolutely identical ornamentation or else *Cyrena securis*

[1] Coquand Aptien de l' Espagne, pl. XIII, fig. 3.

[2] Versteinerungen der jura u. d. Kreide in Deutsch-Ostafrika, 7. Zur Oberflachengestaltung und Geologie von Deutsch-Ostafrika von. W. Bernhardt, Berlin 1900, pl. XX I, figs. 3-4.

[3] d'Orbigny *Pal. Franc.* pl. 260, p. 60.

[4] Entwurf einer Gliederung der Kreideformation in Syrien und Palastina, *Zeitschrift d. Deutsch. Geol. Ges.* 1886, Vol. XXXVIII, pl. XXVI, figs. 2-4.

Meek[1] and *Circe discus* Math[2], both of which are identical in shape, differ in the constitution of the hinge.

The numerous forms of *Astarte* from the Spiti shales are all easily distinguished from the present form.

In the Jurassic of Europe, on the other hand, there occurs a very closely related type, this is *Astartestriato-costata* Gold.[3] from the Malm. In the characters of the ornamentation it agrees perfectly with the Indian form. It is also sometimes narrower (type), sometimes broader (var.); its umbo is, however, less pointed, and the concentric swellings of the early stages are not compressed but are completely rounded, moreover the Indian form is distinctly convex, especially in the umbonal region. The bathonian forms figured by Quenstedt[4] as *Astarte depressa* are even closer, especially with regard to the concentric ridges in the earlier stages of growth, but the posterior margin is more rounded than that of the Indian form, whose general shape is more distinctly triangular. This latter distinction also holds good for *A. striato-costata* in Lahusen[5] from the Oxfordian. *Astarte trembiazensis* Lor.[6] from the Oxfordian of Switzerland is smaller, less convex and is intermediate, with respect to proportionate height, between the two Indian varieties. The interior of the lower margin is similarly crenulated.[7]

Common. East of Laptel E. G. Hundes.

BELEMNITES sp. related to B. Gerardi, pl. 19, figs. 11, 12.

There are two specimens of a small belemnite with a narrow groove. In section it is round or slightly oval. The state of preservation is insufficient to say anything definite about furrows or concentric markings. There is no indication of lateral grooves. There is a great resemblance between this fossil and *Belemnites Gerardi* Oppel from the Spiti shales[8] in which the furrow is broader, though the section is analogous. The early stages of *B. alfuricus*

[1] Stanton, *Bull. U. St. Geol. Surv.*, pl. 106, fig. 23, figs. 1-3.

[2] Gosaubivalven, *Denkschr. k. Akad. Wien.*, Vol. XXIV, pl. III, fig. 7.

[3] Petr. Germ., pl. 134, fig. 18*a*, *b*.

[4] Jura, Vol. LXVII, figs. 29, 30.

[5] *Mem. com. geol. russ.* 1, Die Fauna der jurass. Ablagerungen d. Rjasan Gouv. pl. II, fig. 26.

[6] *Schweizer palæont. Abhandlungen*, Vol. XXVIII, pl. IV, figs. 24-26.

[7] See also the quadrangular *Astarte Wiltoni* and the orbicular *A. angulata* in Morris and Lycett, Mon. of the Brit. Great Ool Moll. pl. IX, fig. 16 and pl. XXXV, fig. 20 from the bathonian.

[8] See Uhlig, Spiti shales, *Pal. Ind.* (15), Vol. IV, of 386.

Bohm.[1] are even closer. Dr. Folgner has kindly informed me that *B. Gerardi* also occurs in the neocomian of the Salt Range. On the other hand, the fossil in question does not resemble any upper Cretaceous forms.

Two specimens. East of Laptel E. G. Hundes.

EXPLANATION OF PLATES.

PLATE 18.

The fossils figured in this plate all belong to the Gieumal sandstone, with the exception, possibly, of figure 9.

FIG. 1*a*, *b*.—*Hoplites* (*Parahoplites*) sp. natural size, Lingti R., p. 205.
FIG. 2.—*Stoliczkaia* cf. *dispar* Orb., natural size. Lingti R., p. 206.
FIG. 3.—*Cardium* n. sp. ind. left valve, natural size. Gieumal, p. 199.
FIG. 4.—*Cardium* cf. *Gieumalense* n. f. right valve, natural size, Gieumal; p. 199.
FIG. 5*a*, *b*, *c*.—*Cardium Gieumalense*, n.f. right valve, natural size. Gieumal; p. 198.
FIG. 6.—*Pseudomonotis superstes* n.f. left valve. natural size. Gieumal. Ornamentation completed from another specimen, p. 201.
FIG. 7.—*Pseudomonotis superstes*, n.f. right valve, natural size, Gieumal, p. 201.
FIG. 8.—*Avicula ?* aff. *Sanctæ-Crucis* Pictet-Camp. natural size, Gieumal. Umbonal region restored from another specimen, p. 207.
FIG. 9*a*, *b*.—*Corbis ? montana* n.f. natural size. Gieumal, p. 210.
FIG. 10.—*Panopæa* cf. *arcuata* Orb., natural size, Gieumal, p. 209.
FIG. 11*a*, *b*.—*Cardium* n.sp. Gieumal.
11*a* natural size, 11*b*, ornamentation, enlarged.
FIG. 12.—*Aporrhais* aff. *Dupiniana* Orb. (in Pict-Camp) cast. natural size. Chikkim, p. 204.
FIG. 13*a*, *b*.—*Lima* aff. *Arzierensis* Loriol. Gieumal.
13*a* lateral view, natural size; 13*b* ornamentation, enlarged, p. 207.
FIG. 14.—*Lima* aff. *Arzierensis* Loriol. cast. natural size. Gieumal, p. 207.
FIG. 15.—*Tapes Rochebruni* Zitt. natural size. Chikkim. p. 203.
FIG. 16.—*Unicardium* cf. *tumidum* Briart-Cornet (in Geinitz). natural size, Chikkim. p. 203.
FIG. 17*a*, *b*, *c*.—*Arca* sp.
17*a*, outline, natural size;
17*b*, the same enlarged;
17*c*, cast, natural size. p. 202.
FIG. 18.—*Tellina* cf. *strigata* Goldf. Right valve. natural size. Gieumal, p. 204.
FIG. 19.—*Tellina* sp. Right valve. natural size, Gieumal, p. 201.
FIG. 20*a*, *b*.—*Gryphæa* aff. *Baylei* Guér, natural size. Gieumal, p. 200.

[1] Niederlandisch Indien Pal. Suppl. IV, pl. VIII. figs. 8, 9.

FIG. 21.—*Gryphæa* aff. *Baylei* Guér. ; view of the umbo. natural size, Gieumal, p. 200.

FIG. 22.—*Pecten* sp. natural size. Gieumal, p. 200.

PLATE 19.

A. Fossils from the Gieumal sandstone.

FIG. 1*a*, *b*, *c*, *d*.—*Opis*. Cast. natural size. Gieumal, p. 207.

1*a*, anterior view.

1*b*, posterior view.

1*c*, lateral view.

1*d*. vertical view from above.

FIG. 2.—*Opis* sp. Cast. natural size. anterior view. Gieumal, p. 207.

B. Fossils from the so-called.

" Chikkim Limestone " of Hundes (Griesbach-collection) from east of Laptel E.G.

FIG. 3.—*Astarte* (*Eriphyla ?*) *hundesiana* n.f. Broad variety. natural size. p. 220.

FIG. 4.—*Astarte* (*Eriphyla ?*) *hundesiana* n.f. Broad variety. natural size. p. 220.

FIG. 5. —*Astarte* (*Eriphyla ?*) *hundesiana* n.f. Broad variety. natural size. p. 220.

FIG. 6*a*, *b*.—*Astarte* (*Eriphyla ?*) *hundesiana* n.f. Type. natural size. p. 220.

FIG. 7. —*Astarte* (*Eriphyla ?*) *hundesiana* n.f. Type. natural size. p. 220.

FIG. 8.—*Cucullæa Uhligi* n.f. natural size. p. 219.

FIG. 9.—*Cucullæa Uhligi* n.f. Ornamentation enlarged. The dots indicate the region to which this portion of the shell belongs. p. 219.

FIG. 10*a*, *b*.—*Cucullæa Uhligi* n.f. natural size. p. 219.

FIGS. 11*a*, *b*, 12*a*, *b*.—*Belemnites* sp. natural size. p. 222.

FURTHER DESCRIPTION OF INDARCTOS SALMONTANUS PILGRIM, THE NEW GENUS OF BEAR FROM THE MIDDLE SIWALIKS, WITH SOME REMARKS ON THE FOSSIL INDIAN URSIDAE. BY GUY E. PILGRIM, D. SC., F. G. S., *Officiating Superintendent, Geological Survey of India* (With Plate 20).

The Specimen.

THE specimen which forms the main subject of the present paper is a fragment of the left maxilla of a bear, containing the perfectly preserved m², with m¹, which has the surface of the crown entirely hammered off, and the alveolus of the posterior root of pm⁴. A part of the zygoma is included showing the maxillo-jugal suture. A narrow strip of the palatine is also visible showing a portion of the maxillo-palatine suture. A small piece of the matrix is attached to the specimen, consisting of the pepper and salt sandstone with grains of medium fineness, which is so frequently met with in Middle Siwalik horizons.

Horizon.

This specimen was obtained from near the village of Hasnot, the well-known locality north of the Salt Range and west of the Tilla ridge, shown in the map which accompanied the author's paper on the correlation of the Siwaliks with Mammal horizons of Europe,[1] which has yielded so many remains of fossil mammals. It was given to Sub-Assistant Vinayak Rao by a villager and its exact locality was not ascertained. The character of the matrix, however, renders it likely that it came out of the Dhok Pathan zone. The possibility cannot, however, be entirely excluded that it may have occurred in the Tatrot beds, although the coarse grit or brownish sandstone so typical of the latter horizon are alike wanting in the portions of matrix attached to the specimen.

Description of the Specimen.

This maxilla was briefly described in *Records, Geol. Surv. India,* Vol. XLIII (1913), p. 290, but without a figure. It was there stated that it was impossible to refer it to any previously known genus, and the name of *Indarctos salmontanus* was proposed for it. The following description is a far more detailed one and is accompanied by figures in Plate 20.

[1] *Records, Geol. Surv. Ind.*, XLIII, Pl. 27.

The structure of the hindermost tooth, which combines characters peculiar to the last upper molar of *Hyænarctos*, *Ursavus*, and *Helarctos* leaves no room for doubt as to its belonging to a member of the family of the Ursidæ. Four main cusps are indicated in m^2 of which the two outermost are stronger; the antero-internal cusp is long and ridge-like and shows clearly a division into two. The postero-internal cusp lies somewhat behind the level of the postero-external one; behind these two cusps the tooth is prolonged into a very strong talon containing a low cusp internally and a small one externally, hanging on at the base of the large postero-external cusp.

The strong external cingulum runs into this latter cusp. There is also a well marked internal cingulum on the anterior two-thirds of the tooth. The talon is not symmetrically developed but is chiefly internal. Thus it comes about that the small external cingular cusp referred to above is connected to the hindermost point of the tooth by a straight marginal edge oblique to the antero-posterior axis. The surface of the tooth seems to be quite smooth and free from wrinkling.

	Indarctos salmontanus.	Hyænarctos punjabiensis.	Arctotherium bonariense.	Ursavus brevirhinus.	Helarctos malayanus.	Ursus namadicus.	Ursus arvernensis.	U. etruscus.	U. isabellinus.
Length of m^2 . .	35	29	50	13	20	28	29	35	34
Breadth of m^2 . .	27	27	35	10·5	13·1	app. 16	16	21	17
Length of m^1 . .	app. 28	28·5	30	12	18	20	20	22	20
Breadth of m^1 . .	app. 25·5	28	35	11	13	17	15	17	15
$\frac{\text{Length of } m^1}{\text{Breadth of } m^1}$ . .	1·09	1·01	·86	1·09	1·38	1·17	1·33	1·29	1·33
$\frac{\text{Length of } m^2}{\text{Breadth of } m^2}$ . .	1·29	1·07	1·43	1·23	1·52	1·75	1·81	1·67	2·00
$\frac{\text{Length of } m^2}{\text{Length of } m^1}$.	1·25	1·01	1·66	1·08	1·11	1·40	1·45	1·59	1·70
Length of pm^4 .	..	29	..	12	11·8	15·6	..	..	..
Breadth of pm^4 . .	..	24·2	..	8	9·1	12	..	..	..
Height of jugal process of maxilla.	app. 45	app. 45	..	..	16·5	..	..	..	..

Measurements of Ursidae.

The measurements of this tooth in millimetres as well as the other dimensions of the specimen are stated in tabular form above together with those of *Ursavus brevirhinus*, *Hyænarctos punjabiensis*, *Arctotherium bonariense*, *Helarctos malayanus* and some other species of *Ursus*.

Comparisons with *Hyænarctos*.

It will be seen that in point of size this species can only be compared with *Hyænarctos* and *Arctotherium* amongst the Ursidæ. Since, however, *Hyænarctos* (taking as the types of this genus *Hyænarctos sivalensis* Falc and *H. insignis* Gerv.) is characterised by perfectly square upper molars, it seems quite impossible to refer the present species to that genus, as not only is m^1 longer than broad, but a very pronounced talon is present in m^2.

Comparisons with *Hyænarctos punjabiensis*.

It cannot, however, be denied that the species *Hyænarctos punjabiensis* possesses precisely those structural features which are so obvious in *Indarctos*, only in a very much less pronounced degree. It is true that m^1 in this species is almost square, but if we refer to Lydekker's figure* of m^2 we shall observe the same prolongation of the postero-internal angle, though it has hardly advanced far enough to be called a talon. If however we should discover a form intermediate between *Hyænarctos punjabiensis* and *Indarctos salmontanus* it would be indeed difficult to draw generic distinctions between the three. It is perhaps unfeasible at present to separate *Hyænarctos punjabiensis* generically from the other known species of *Hyænarctos*, but in any case the features, which distinguish my species from *Hyænarctos sivalensis*, apply, though in a less degree, in a comparison with *Hyænarctos punjabiensis*, and seem to justify the establishment of a new genus for the recent find.

Connection with *Hyænarctos arctoideus*, Dep.

In my preliminary notice† of *Indarctos*, I suggested the possible connection between the Hasnot species and the species from the pontian beds of Montredon briefly described by Depéret under the name of *Hyænarctos arctoideus*‡ but without either figures or dimensions.

[1] *Pal. Ind.* ser. 10, II, text fig., p. 228.
[2] l. c., p. 290.
[3] *Comptes Rendus Acad. Sci., Paris*, CXXI (1895), p. 433.

Schlosser[1] has ventured on identifying Depéret's species with a species of *Ursavus* from the pontian of the Bohnerz of Melchingen to which he has given the name of *Ursavus depereti*. It is not possible to arrive at any conclusion with the meagre information at our disposal regarding the species *Hyænarctos arctoideus*.

Mandible of *Hyænarctos palæindicus*.

I might here withdraw the tentative suggestion made in my preliminary notice of *Indarctos*, that the mandibular fragments (Ind. Mus. D. 9 and D. 10) figured by Lydekker in *Pal. Ind.* ser. 10, vol. II, Pl. 31, figs. 2, 3, and provisionally referred by him to *Hyænarctos palæindicus*, might possibly have belonged to *Indarctos*. The size and prominence of the zygomatic arch points to a mandible much stouter than this. Moreover, the dog-like qualities to which Lydekker calls attention are not such as one would expect in an animal which distinctly approximates to the true bears.

Comparisons with *Arctotherium*.

Arctotherium certainly shows some features of similarity to *Indarctos*, but apart from the improbability that American Pleistocene species, which are mainly southern in their distribution, should be generically identical with an Indian one of pontian age, *Arctotherium*, as typified by the species *A. bonariense*. P. Gerv., seems to be quite distinct from our species even in the few characters that are available for comparison. In *Arctotherium* the transverse diameter of m^1, far from being less than the antero-posterior diameter, often actually exceeds it. On the other hand the talon of m^2 in this genus is longer and more complicated than in *Indarctos*.

Comparisons with *Ursavus*.

I shall next consider the relations of *Indarctos* to the upper Miocene genus *Ursavus*, and compare the two as carefully as my materials allow. *Ursavus* also possesses a talon to m^2, but it is not so long as in the Hasnot species. Moreover, it seems to have been much more symmetrical. The four main cusps form a square, the two posterior ones being directly opposite one another; further there seems to be no trace of a sub-division of the antero-internal cusp into two. *Ursavus* resembles our form in the presence of strong cingula both internally and externally.

We find that the disproportion between length and breadth in m^1 of *Ursavus brevirhinus* is less marked than in the Indian

[1] Schlosser M., Beitrage zur Kenntniss der Saugethierreste aus den Süddeutschen Bohnerzen, *Geol. u. Pal. Abhandl.*, IX (1902), 149.

fossil. Even supposing agreement between the two species in the structure of pm^4 and otherwise, the points I have mentioned seem sufficient to justify a generic separation.

Comparisons with modern bears.

Modern bears with the exception of the South American species, *Tremarctos ornatus* and the Malayan bear *Helarctos malayanus* possess a talon to m^2, which is so much longer and more complicated than the one in question as to entirely preclude any comparison. Of the two exceptions to this, I shall first consider *Helarctos malayanus*. This bear in respect of size of talon in m^2 and relative length of the upper molars is evidently removed as far from our species in the one direction as *Ursavus brevirhinus* is in the other. The antero-internal cusp is divided as in *Indarctos* but in addition, the external cusp, which in the Hasnot specimen is obviously cingular in origin, has assumed much greater dimensions and has been shifted internally so as to be in a line with the two external cusps anterior to it. The talon is more developed externally than in *Indarctos* and is higher, being further complicated by stronger and more numerous cusps. On neither side of the tooth is the cingulum so well-developed as in the fossil, although this appears to be a somewhat variable character.

Comparison with *Helarctos malayanus*.

It has already been remarked that a part of the maxillo-palatine suture is visible in my specimen. The course of this is essentially different not only from what we see in *Helarctos malayanus*, but also in all other modern bears. Running alongside the teeth it does not leave them until it is opposite the midpoint of m^1. On the analogy of the other bears we may infer that it then proceeds obliquely inward at least as far forward as pm^4. In *Helarctos malayanus*, this suture leaves the line of the teeth opposite the hinder half of m^3 and ends up no further forward than m^2. In *U. isabellinus* and its allies it runs as far forward as pm^4 but leaves the teeth opposite m^3.

A point which seems worthy of mention is that in the fossil the maxilla is very much deeper and more stoutly built than in the living form not only absolutely, but in a measure quite out of proportion to the amount by which the molars of the one species exceed those of the other in size. This stoutness extends very markedly to the jugal process and to the jugal bone. A striking feature of the latter

is the extent to which it projects outwards from the face before running backward to join the zygoma. It seems probable that the more massive structure of the maxilla must be correlated not only with larger molars than in the living bears but also with larger premolars. Another small point connected with the fragmentary alveolus of the hinder root of pm^4 leads us with even greater certainty to the same conclusion. In *Helarctos malayanus* as in all modern bears as well as in the pliocene and pleistocene types referable to *Ursus,* the inner cusp (protocone) is situated almost on a level with the hinder outer cusp (metacone), both protocone and metacone being supported on a single root, only slightly inferior in breadth to the entire breadth of the crown of the first molar tooth immediately behind it. In *Hyænarctos* and *Ursavus* on the contrary the protocone lies very much more forward, on a distinct root of its own and the hinder root of pm^4 is comparatively small—less than half the width of m^1. If the Hasnot species possessed a pm^4 of the type of *Helarctos* and *Ursus* the diameter of the hinder alveolus would most certainly have been greater than is actually the case. We may, therefore, infer with a tolerable degree of certainty that the protocone rested on a distinct root and lay more anteriorly than is the case in *Helarctos.* Whether it corresponded exactly in position and size to the protocone in pm^4 of *Hyænarctos* and *Ursavus,* it is, of course, impossible to say. But in any case we are provided with another very important difference in structure from *Helarctos malayanus,* and we need feel no hesitation in placing the Hasnot specimen into a different genus from *Helarctos.*

Comparison with *Tremarctos ornatus.*

Coming now to *Tremarctos ornatus,* it seems that the general appearance of m^2 recalls the Hasnot specimen strongly. Apparently, however, all the internal cusps including those of the talon here become fused into a more or less continuous ridge broken here and there by small divisions. In its hinder part this ridge bounds the talonal margin. In the Hasnot tooth the talon is depressed and shows no trace of any such ridge. In its proportionately longer upper molars, *Tremarctos ornatus* approximates less nearly to *Indarctos* than does *Helarctos malayanus.* In other respects the points to which I have called attention as separating the two latter apply equally well to distinguish the fossil form from the recent South American species. It would, therefore, be quite unreasonable to attempt to trace a connection with such a geographically distant animal.

Ancestry and later history of *Indarctos*.

Passing now to the question as to (1) how the *Indarctos* type may have originated, (2) what it may have given rise to in later times, we must first reject the idea suggested in my first notice of this genus that *Helarctos malayanus* may have been its degenerate descendant. Although the structure of m^3 in the modern species is somewhat similar, yet the greater complication of the cusps and still more the difference in pm^4 is entirely against this theory. It seems most likely that *Indarctos salmontanus* represents the climax in size attained by this particular line which soon after became extinct, as has so frequently been proved to occur in such gigantic types.

As to its origin, it is of course not beyond the bounds of possibility that it may have descended from the tortonian or sarmatian *Ursavus*, or a closely allied form, but the much greater degree of corrugation in the latter and the more symmetrical talon of m^2 militates against it. We see moreover in the pontian *Ursus Bockhi*, which according to Schlosser is the direct descendant of *Ursavus*, the development of the *Ursavus* features along the very lines which one would have expected them to follow.

Considering the structural peculiarities shared in common by *Indarctos salmontanus* and *Hyænarctos punjabiensis*, to which attention was drawn on page 227, the question of a possible genetic connection at once suggests itself. Apart from the fact that both these species are believed to occur at the same stratigraphical horizon, it is unlikely that the one form is the lineal descendant of the other, for *Hyænarctos punjabiensis* has a deeper maxilla, but it seems highly reasonable to suppose that both of them represent slightly different lines of development from a smaller and less specialized *Hyænarctoid* ancestor. Such a form or a near ally of it suggests itself in the sarmatian *Hyænarctos laurillardi*, Menegh. from Monte Bamboli, but even smaller species conforming to the required structure may one day be found in the Lower Siwaliks, which up till now has yielded no Ursid remains whatever.

Since to my knowledge no upper teeth have been discovered either in the case of *Hyænarctos laurillardi* or *Hyænarctos atticus*, Dames, it is possible that one or both of them may have possessed the embryonic talon shown in m^2 of *Hyænarctos punjabiensis*.

It is doubtful how far the presence of such a talon in the last upper molar may be correlated with the size of the 3rd lower molar. It may be noted however that m_3 in *Hyænarctos sivalensis* is said to

have been comparatively small, and in *H. palæindicus* was either very small or absent. This tooth is unknown in *H. insignis.* On the other hand it is comparatively large in *H. laurillardi,* and moderately so in *H. atticus.* In this connection I would suggest that it might be wiser to consider the reference of the mandible figured by Lydekker in *Pal. Ind.* ser. 10, vol. II, Pl. 31, fig. 1 to *Hyænarctos punjabiensis* as provisional. The mandible in question was not obtained in the same season as the type maxilla, and so far as can be seen now the two specimens do not agree exactly either in colour or amount of wear, and therefore are unlikely to have belonged to the same individual, which was Lydekker's opinion at that time. Failing exact knowledge as to the actual association of the two, it seems as likely that the mandible belonged to the species *Indarctos salmontanus.*

Hyænarctos sivalensis and insignis.

No trace of a talonal structure exists in m^2 of either of the species *H. sivalensis* or *H. insignis.* As we have very strong reason to believe that both of these species occur at a considerable higher stratigraphical horizon than *H. punjabiensis,* we may infer that they are descended from a species which, in this respect at all events, was more primitive than *H. punjabiensis. H. insignis* was a smaller form, but the degradation of pm^2 to a single-rooted tooth in distinction from the double root of the corresponding tooth in *H. punjabiensis* is what might be expected in a later Ursid species.

Hyænarctos palæindicus.

Yet another line existed in the Middle Siwalik of India as the species *Hyænarctos palæindicus,* the dog-like affinities of which have been clearly shown by Lydekker.* The shortness of m^1 and the rounding off of its internal angles together with the obliquity of the external cusps of m^2 indicate, according to Lydekker, a nearer relationship to *Hemicyon* than is found in any other *Hyænarctos* maxilla. The supposed mandible of this species exhibits in its shallowness and slenderness, and in the absence of m^3 even greater unlikeness to the bears. In many respects this mandible reminds one of *Simocyon.*

Melursus theobaldi.

Passing to the true bears, ancestral forms such as are found in Europe in *Ursavus* and *Ursus bockhi* are absent from the Miocene and Lower Pliocene of India. The earliest Indian bear is the species *Ursus theobaldi*

[1] *Pal. Ind.* ser. 10, II, p. 232.

Lyd. from Kangra, the horizon of which is probably the Boulder Conglomerate zone, equivalent to the Upper Pliocene of Europe.

Lydekker* has clearly shown that this is to be assigned to the genus *Melursus*, and regards it as the direct ancestor of the recent *Melursus ursinus*, from which it follows that the aborted dentition of the latter is a recently acquired characteristic and not a survival of ancestral characters.

Ursus namadicus.

The only other fossil bear is *Ursus namadicus* of the Pleistocene of the Narbada valley. This species seems to me to be much closer to *Ursus arvernensis* Croiz. et Job. of the Upper Pliocene and Pleistocene of Europe than to *Ursus (Helarctos) malayanus* differing from it so far as concerns the upper dentition (which is alone known in *U. namadicus*) only by the broader m^1 and the larger and more posteriorly situated protocone of pm^4.

It may be permissible to place both of these forms into the subgenus *Helarctos*, but I am unable to regard *Ursus namadicus* as the direct ancestor of *Ursus (Helarctos) malayanus* in view of its much more elongated m^2. Schlosser† comments on its likeness to *Ursavus brevirhinus*. These two species indeed correspond in the breadth and simple structure of m^1, but the great difference of their geological ages amply accounts for their unlikeness in other respects. But in any case it may well be that *Ursus namadicus* and *Ursus arvernensis* represent another line apart from *Ursus (Helarctos) malayanus.*

The mammalian fauna of the older pliocene of India is too insufficiently known to allow us to be sure that the failure to find *Ursus* at this horizon is a proof of its actual absence from the fauna. Hence, though tempting, it would be premature to draw any deductions as to the migration from Europe to India of bears like *U. ruscinensis* or *U. arvernensis*, through stress of climatic conditions in the glacial period.

EXPLANATION OF PLATE.

PLATE 20.

FIG. 1.—*Indarctos salmontanus*, Pilgrim, left maxilla, surface view.
FIG. 2.—m^1 in the above, external side view.
FIG. 3.—the same, internal side view.

[1] *Pal. Ind.* ser. 10, II, p. 211.
[2] Schlosser M. Ueber die Bären and Bärenähnlichen Formen des Europäischen Tertiärs *Palæontographica*, XLVI (1899), p. 100.

ON THE PROBABLE FUTURE BEHEADING OF THE SON AND RER RIVERS BY THE HASDO. BY L. LEIGH FERMOR, D. SC., A.R.S.M., F.G.S., *Superintendent, Geological Survey of India.* (With Plate 21.)

Perhaps the most remarkable feature in the physical geography of Korea State is the direction of its drainage system. From the accompanying map it will be seen that with small exceptions the whole of the portion of the State represented—namely, that south of lat. 23° 30′, corresponding roughly with the portions of Korea south of the Supra-Barakar plateau, and forming about three quarters of the total area of the State—is drained by the Hasdo and its tributaries, the Budra, the Anjan, and the Gej. The exceptions are the north-west corner, which is drained by the Kewai, a tributary of the Son, flowing through Rewah State to the west; and the north-east borders, which are drained by tributaries of the Rer in Sarguja State to the east. The Hasdo is, of course, a tributary of the Mahanadi, so that the main drainage of Korea finds its way to the sea at Cuttack. But Rewah State and Pendra zemindari on the west of Korea are drained almost entirely by the Son already mentioned, and Sarguja on the east by the Rer. Both these rivers flow northwards, the Rer joining the Son in the Mirzapur district, and the Son being one of the main tributaries of the Ganges. The northern portions of Korea are also drained by tributaries of the Son, the Supra-Barakar rocks of the Deogarh range forming the watershed.

Southern Korea thus forms a drainage wedge, of which the waters flow south to the Mahanadi, driven in between two drainage areas the waters of which flow north to the Ganges. A reference to the map of India shows that the water flowing north *viá* the Ganges route has more than twice as far to travel before reaching the sea as water pursuing the southern route *viá* the Mahanadi. One is, therefore, not surprised to find that the Hasdo in its Korean course has a much steeper gradient than the upper reaches of the Son and the Rer on either side.

At Sanhat (Lat. 23° 29′) the Hasdo flows at a level of about 2,400 feet, whilst where it leaves the State in the south (Lat. 22° 59′) it is at only about 1,200 feet[1]. The Rer on the east shows a fall of not more than about 200 feet (approx. from 1,800 to 1,600 feet) in traversing, in a northerly direction from Jajga on the south to Jhilmili in the north, the same number of minutes of latitude, whilst the Son, pursuing an average northerly to north-west course through the Pendra zamindari and the Sohagpur tahsil of the Rewah State, falls from about 1,900 feet east of Pendra (Lat. 22° 45′) to about 1,450 feet near Sohagpur (Lat. 23° 19′) to the west of the present sheet, in a course of about the same length. The gradients are thus roughly as follows:—

Hasdo .	1,200 feet in	76 (34) miles	or 16 feet to the mile[2].
Son . .	450 feet in	75 (50) miles	or 6 feet to the mile.
Rer . .	200 feet in	62 (33) miles	or 3 feet to the mile.

Taking not the distances along the bends, but measurements in a straight line, Korea may be likened to an inclined plane with a gradient of 35 feet to the mile to the south, placed between two inclined planes dipping respectively at 9 feet to the mile to the north-west, and 6 feet to the mile to the north, the base of the Korean inclined plane being roughly on the same latitude as the summits of the Rewah and Sarguja planes and *vice versa*. Consequently, the Hasdo, where it leaves Korea in the south, is flowing at a much lower level than the Son and the Rer on the same latitude. In latitude 23° 0′ the Hasdo is flowing at about 1,200 feet, whilst the Son at the same latitude is at about 1,700 feet, and the Rer at about 1,800 feet. At this latitude the Son is only 20 miles to the west of the Hasdo, and the Rer only 38 miles to the east. It is, therefore, obvious that any tributaries of the Hasdo at this latitude flowing from either the west or the east must have relatively high gradients—higher indeed than the Hasdo itself, and very much higher than the Son and the Rer each of which is pursuing a fairly level course, largely alluvial, on elevated country on either side of the Hasdo.

[1] Very few heights are attached to the rivers on either the Atlas Sheet or the 1-inch maps of this country so that I am compelled to deduce approximate heights for given points from (1) such heights as are given in the neighbourhood, (2) the contouring of the maps and (3) such local knowledge of the country as I obtained during my visit.

[2] Distances measured along the bends. The numbers in brackets are the distances measured in a straight line

Sooner or later, therefore, such tributaries should have a chance of beheading the upper reaches of the Son to the west and of the Rer to the east and of diverting their drainage into the Hasdo.

A reference to the map reveals at once two excellent cases where tributaries of the Hasdo have cut back the watershed very close indeed to the Son on one side and to the Rer on the other.

The beheading of the son.

On the west side, the Budra river—which joins the Hasdo at an elevation of a little over 1,200 feet some 2 miles below Dewadand near the southern border of Korea—rises to the west and south-west in a multitude of tributaries, a large number of which head within 1 to 4 miles of the Son. The watershed between the Son and these nalas is very low and is frequently, judging from the 1" map and my observations where I crossed it at two points, of an alluvial character, and is, therefore, in many places probably not more than 50 feet, and probably sometimes less, above the bed of the Son. It seems, therefore, certain that sooner or later the Son will be tapped at one of these numerous points of attack.

This may happen in two ways. *Either* a tributary of the Budra may erode back its head until it reaches the flood level of the Son in the rains, when the Son will discover this channel and commence deepening it with a rush of water. If the barrier were alluvial this cutting might be completed in one rains with the consequent diversion of the head waters of the Son into the Budra. But if the barrier were rocky it would probably take many years to deepen the channel to the level of the bed of the Son; and in such a case water from the Son would pass into the Budra only during the rains year by year, until a permanent diversion was effected. *Or secondly*, the Son might in a season of exceptionally heavy rains reach an abnormal level and overflow its banks, thus entering one or more of the attacking tributaries years earlier than would otherwise have happened.

Once the diversion had been effected, the gradient of the captured portion of the Son would speedily increase, and a gradually increasing length of the Son below the point of truncation would have its flow reversed.

The distance to which this reversal would, in the course of time, extend would naturally depend on the character of the watershed between the two drainage systems at the point where

it was breached, particularly the depth of sound rock below the surface, and its power of resisting erosion. But it seems likely that in any case the reversal would eventually extend as far as the junction of the Kewai with the Son (about 1,600 feet), thus also diverting into the Hasdo the drainage of the Kewai, which taps the north-west corner of Korea.

If we examine the 1″ sheets for the most likely spots at which such beheading might occur, three points seem to be specially favourable. One of these is a point about a mile south-west of Nakha (Lat. 22° 55′), where a tributary of the Sukhar, itself a tributary of the Budra, terminates only half a mile east of the Son, from which a minute tributary rises up to join hands. The watershed at this point may be a trifle high, as is suggested both by the contouring and by the existence of granitic outcrops just to the south of the nala : it cannot, however, be higher than 100 feet above the Son, and is probably much less. In addition the attacking tributary falls eastwards, in the course of a mile, to a much lower level than the Son, so that the watershed is bound to be breached sooner or later.

An almost equally likely spot lies on this same watershed some 3 miles further north near the village of Karangi (23° 57′). Half a mile east of this village the Dumar rises less than a mile from the Son, the height of the watershed above the Son being probably not more than about 50 feet. The Dumar has a considerably steeper gradient than the tributary of the Sukhar that is pushing the attack near Nakha. Thus, where it joins the Budra the elevation is about 1,400 feet, whilst on the watershed its elevation must be a little less than 1,800 feet. There is thus a fall of nearly 400 feet in the course of 6 miles, whilst the gradient in the Sukhar must be about 450 feet in about twice that distance. Without a more intimate knowledge of the ground it is impossible to predict which of these two tributaries will effect the beheading.

If the two tributaries noticed above are slower in their action than might be anticipated, then the capture may be effected still further to the south near the villages of Sakhua and Sakola (Lat. 22° 50′), where several of the head tributaries of the Sukhar approach within 1½ to 1¾ miles of the Son, at a point where the map suggests that the watershed lies on alluvial ground. Although these tributaries have a low gradient at this point, so

that they will tend to cut back their heads more slowly, other things being equal, yet the height of the watershed above the Son must be very small, giving the latter river so much the greater chance of overflowing its watershed at a time of exceptional floods and so beheading itself.

Still further south the beheading might be effected by tributaries of the Bamni, the largest tributary of the Budra. But it seems to me that the beheading of the Son is more likely to occur at one of the first named points lower in the course of the Son, because the attacking tributaries near Karangi and Nakha have a steeper gradient, whilst the Son itself is larger and perhaps has a greater chance of entering the invading nalas at times of exceptional floods.

The beheading of the Rer.

Turning now to the eastern side of the Hasdo, it is seen at once that the Jhink Nala, a tributary of the Gej, which itself falls into the Hasdo some miles below where the latter leaves Korea, has already cut back its course so far that at Bhaduai (Lat. 23° 1′ Long. 83° 0′), two of its headwaters have reached a distance of only a mile from the Rer. The contouring of the 1′ map at this point suggests that the watershed between the Jhink and the Rer is fairly high above the Rer, perhaps 100 to 150 feet. But it seems certain that sooner or later the Jhink will behead the Rer at one of these two points. The probability of this is seen in the fact that the Jhink falls some 450 feet between its source and its junction with the Gej (about 1,400 feet) some 23 miles to the west. Between the probable point of beheading and Jhilmili—some 52 miles—the Rer falls from about 1,750 or 1,800 feet to a little over 1,600 feet (Jhilmili is 1,634 feet), probably 150 to 175 feet in all; comparing this elevation with that of the junction of the Gej and the Hasdo, it does not seem likely that a very great length of the Rer below the point of truncation will have its course reversed and turned into the Jhink. This probability is strengthened by the fact that below Jhilmili the Rer passes through rocky country with a much increased gradient, falling in the course of 50 miles from about 1,600 feet at Jhilmili to 1,074 feet at the Rehund H.S. (Lat. 23° 53′). So that eventually, indeed, the Rer is likely to recapture its lost headwaters when the barriers that must exist in this lower part of its course are eroded away.

Before this stage is reached, however, we may picture a period of great increase in the catchment area of the Hasdo, when the upper reaches of the Son (and of its tributary the Kewai) in Pendra and Rewah, both discharge their waters down one of the tributaries of the Budra into the Hasdo, and when the upper reaches of the Rer in Sarguja, perhaps as far down stream as Paharbula (Lat. 23° 11′) but probably no further, discharge their waters *viâ* the Jhink and the Gej also into the Hasdo.

Date of beheading.

To assign a date to this truncation is, of course, impossible in our present ignorance, not only of the exact data relating to this particular case, but also of rates of erosion and weathering in general. But, considering the proximity of the headwaters of the Budra to the Son and the insignificance of the intervening watershed, surprise should not be felt if the capture of the headwaters of the Son take place within the present century. The reader will perhaps best understand the probability of this ultimate beheading in the case of the Son by a glance at the map, the shading of which shows admirably the manner in which the multitude of relatively steeply graded tributaries of the Budra are cutting into the edge of the plateau on which the Son in false security pursues its meandering course.

Geological reasons for direction of drainage of the Hasdo.

It is difficult to advance definite reasons based on geological structure to explain this occupancy by the Hasdo of the larger portion of Korea State. The primary consideration is, of course, gradient to the sea, and it is likely that the country now drained by the upper reaches of the Son would also have been drained long ago by a southward-flowing river, were it not for the fact that the Pendra plateau, acting as the watershed between the drainage of the Bilaspur district to the south and of Rewah to the north, is composed of Archæan granites and gneisses, which have probably acted as a buttress against rapid erosion from the south, permitting the Gondwanas lying to the north of this buttress to be eroded and drained by a northward-flowing river of low gradient. This buttress is, of course, the extension of the protaxis of the Satpuras, which, as the author has discussed elsewhere[1], probably continues eastwards as far as the Ranchi plateau.

[1] Fermor, Geology and Coal Resources of Korea State, *Mem.*, *Geol. Surv., Ind.*, vol. XLI, pt. 2, p. 164.

But if one considers the long strip of Gondwana sediments stretching from Rewah through Korea and Sarguja nearly continuously in a south-east direction as far as the Talchir coalfield, one cannot help thinking, in spite of the fact that portions of the boundaries of this strip are faulted, that the sediments were deposited by a great river flowing south-east to the sea through a breach in the Satpuran protaxis in Korea and western Sarguja. The Vindhyan pebbles in the glacial boulder beds of the Talchirs in Korea were probably derived from Baghelkhand in the north-west and support this hypothesis. If this view be correct then the Hasdo is merely opening up once more this ancient pre-Gondwana channel across the Satpuran protaxis. Where I have indicated the probability of one of its tributaries tapping the Son, the latter is flowing on top of the ancient Archæan Satpuran ridge, and consequently, owing to the relatively slow rate of erosion of the Archæans, the time of truncation of the Son may be more remote than I imagine, and beheading in this neighbourhood may be anticipated by one of the more northern tributaries of the Hasdo, such as, the Kulharia, working on the softer materials of the Gondwanas and thus tapping the Kewai directly.

In western Sarguja to the east of Korea the geological relationships seem to be less simple, and it is still more difficult to explain satisfactorily the northward drainage. But it is probably influenced by the fact that the continuation of the Satpuran protaxis to the east of the Korean breach begins to rise again in western Sarguja.

EXPLANATION OF PLATE.

PLATE 21.

Geological Map of Korea State. Scale 1″=4 miles.

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NOTES ON THE SALT DEPOSITS OF THE CIS-INDUS SALT RANGE. BY W. A. K. CHRISTIE, B.Sc., Ph.D., *Chemist, Geological Survey of India.* (With Plates 22 to 28 and text figure 12.)

The Rock Salt Deposits.

THE Cis-Indus Salt Range consists essentially of a narrow plateau with an average elevation of two to three thousand feet, extending westwards for about a hundred and fifty miles from the Jhelum to the Indus river. On its southern side, where most of the salt exposures occur, it descends steeply to the great plains of the peninsula, forming a rugged escarpment broken by wild, precipitous gorges carved out by the streams from the highlands.

In the Range there is represented a geological sequence unrivalled in completeness in any other part of India, and the problems it presents, stratigraphical and palæontological, have given rise to an extensive literature. The salt deposits with which this paper deals have been described by many observers, the most detailed accounts being those of A. Fleming[1], H. Warth[2] and A. B. Wynne[3], who gives a geological bibliography up to 1876. They occur in a formation of peculiar appearance known as the Salt Marl- a red, friable, fine grained clay carrying large quantities of salt, gypsum and sometimes dolomite—which generally underlies all the other formations in the Range.

[1] *Jour. As. Soc. Beng.*, *22* (1854), 239.

[2] Report on the Administration of the Inland Customs Department for the official year 1869-70, Calcutta, 1871, Appendix II ; *ibid.*, 1871-72, Calcutta, 1872, Appendix D, *Öst. Zeit. f. Berg-u. Hüttenwesen*, *24* (1876), 397 and 407.

[3] *Mem. Geol. Surv. Ind.*, *14* (1878), 70.

Rock-salt is mined principally at Khewra (lat. 32° 39′; long. 73° 3′), but there are subsidiary mines at Warcha (lat. 32° 24′· long. 72° 0′) and at Nurpur (lat. 32° 38′; long. 72° 38′). The salt deposits worked at Khewra are contained within the Mayo Salt Mine Hill (Plate 22), which rises to a height of about 200 metres above the level of the river which flows at its base. It is isolated by gorges in all directions, except towards the E.-N.-E., where it is covered by Purple Sandstone. The salt deposits so far proved have a thickness of some 200 metres, of which, however, only about half is pure enough for sale. The general strike is E.-N.-E.—W.-S.-W. The dip varies from 0° to 60°—it is generally less than 45°—N.-N.-W., with an occasional instance of a dip to S.-S.-E. The salt is divided into three main seams, Buggy at the top, then Sujowal, then Pharwala, these being separated from one another by layers of "kallar" or marl—salt too impure to be marketable. The Buggy and Pharwala sections are further subdivided into three by subsidiary "kallar" seams, but in the case of the former section these thin out as they are followed down the dip, as do also the marl seams separating Buggy from Sujowal. Salt has been mined at Khewra for hundreds of years, but it is only since 1870 that any system has been adopted, and all the older workings have been abandoned on account of their dangerous character. According to the present system nine-metre pillars are left between successive working blocks and run uninterruptedly throughout their entire length. The working blocks, of which there are thirty-seven, are each twelve metres wide and run at right angles to the strike of the beds. Their height and length are limited mainly by the occurrence of "kallar" seams and occasionally brine; the largest is about 50 metres high and 185 metres long. All the chambers are entered from two main levels, the tramway system in each converging on one main exit. Forward workings are generally begun on the upper portion of a seam and the floor blasted away in steps. The blast holes are all made by hand and ordinary gunpowder is the explosive used. A typical miner is shown in plate 24, with his jumper (*gadela*), pick (*howri*), scraper (*karandi*), pricker (*sua*), oil-bottle (*tel ki kuppi*), powder flask (*daru ki kuppi*)—both of leather—hammer (*martol*) and open oil lamp (*dewa*). The work of excavation is done by men, women and children being employed to transport the salt to the tramway. It is then run by gravity on a gentle incline to a depôt on the North-Western Railway, where it is hand picked, not only from "kallar", but from small salt (less than

half a centimetre cube), for which there is no demand, and despatched in bags. About 100,000 metric tons of salt *per annum* are raised from the Mayo mines at a cost (including administrative charges) of about Re. 1-13 per ton.

Its average quality is shown in the following analysis by E. H. Hankin, Chemical Examiner to the Government of the United Provinces of Agra and Oudh. The figures, kindly supplied by the Department of Northern India Salt Revenue, refer to the salt obtained from the Mayo mines in the year 1910-11 :—

	Per cent.
Insoluble matter	0·10
Na_2SO_4	3·20
$NaCl$	96·10
$MgCl_2$	0·60
	100·00

The Potash Deposits.

Potassium bearing salts were discovered in the Mayo mines in 1873 by H. Warth. The specimens collected by him, consisting of mixtures of kieserite, sylvite and langbeinite, with common salt, have been described by a number of writers.[1] The deposit, however, was lenticular and the total quantity obtained was only 15 maunds (560 kg.).[2]

On account of the great economic value of salts of potassium, chiefly for agricultural purposes, and the restricted area of their production,—practically the whole of the world's supply comes from the North German mines—prospecting operations were carried out in the mines of the Salt Range, and further deposits have been found, in the Mayo Mines at Khewra and at Nurpur.

In prospecting for these salts physical tests such as lustre, taste, hardness, solubility, flame colouration etc., are very uncertain criteria, and chemical methods, although not so convenient, were therefore adopted. Perchloric acid was found to be the most convenient reagent for the purpose. About one gram from the stratum to be tested was removed in fine powder by means of a 1 cm. hand

1 {
G. Tschermak, *Min. Mitt.*, 1873, 135
H. Warth, *Öst. Zeit. f. Bergu. Hüttenwesen*, *24* (1876), 408.
A. Tween, *Mem. Geol. Surv. Ind.*, *14* (1878), 80.
F. R. Mallet, *Mineral. Mag.*, *12* (1900), 159.
}

2 F. R., Mallet, "Manual of the Geology of India,' Part 4, 33; Calcutta, 1887.

drill, shaken with about three ccm. of water for some time (langbeinite is only slowly soluble) filtered if necessary, and the solution treated with a few drops of perchloric acid (s. g. 1·125). The absence of a white precipitate of the perchlorate indicates that the stratum, if containing any, does not carry sufficient potassium salts to make it of any economic value, while the volume of the precipitate, when there is one, gives a rough index of the richness of the deposit.

The Department of Northern India Salt Revenue, by which the mines are worked, has hitherto been concerned only with the recovery of marketable salt, of which there exists an unlimited quantity; they have, therefore, naturally altered the direction of their workings on striking a seam of marl or impure salt of any considerable thickness, and before the underlying strata were exposed. Most of the occurrences of potassium salts are overlain by marl seams, and the exposures, consequently, are neither frequent nor easily followed out. I would take this opportunity of expressing my thanks to the officers of the Salt Department for their assistance, and especially to the Superintendent of the Mayo mines, Mr. F. Reid, whose knowledge of their intricate workings is nearly as manifold as his kindness.

A list of the localities where potassium salts were found in these mines is given below. The numbers refer to the chamber series, there being a distance of 21·3 metres in a direction N. 60° E. from the median line of chamber n to that of chamber $n+1$. The localities are characterised in terms of the phraseology locally current :

a No. 9, 3 metres S. of new tram, below the top seam of Pharwala-Sujowal marl.

b No. 9, 33·5 metres from entrance of drift N. of Buggy.

c No. 9-10 pillar, 4 metres S. of new tram, 0·5 metres below marl seam.

d No. 10, drift block Pursang, 1 metre below the highest seam of the hundred foot marl.

e No. 12, Pharwala exploring drift, 33 metres from the mouth.

f No. 12, Pharwala exploring drift, 83 metres from the mouth.

g No. 13, Pharwala, end of ten foot drift underlying marl seam below 544 salt.

h No. 14, Pharwala, S. end of drift.

i No. 14-15 pillar, N. of old tram.

j No. 16, Pharwala drift, immediately below hundred foot marl.
k No. 16, Pharwala drift, 1·2 metres below hundred foot marl.
l No. 19, Buggy-Sujowal, below the second of the marl seams of Pharwala—Sujowal marl.
m No. 22, Pharwala, mouth of exploring drift.
n No. 22, Pharwala, 53 metres from mouth of exploring drift.
o No. 26, Pharwala, mouth of old drift, underlying highest marl seam.
p No. 26, Pharwala, Nur Mahomed's drift, in fourth highest marl seam.
q No. 27, Buggy, beneath stairway at S. end.
r No. 29, Buggy, below Buggy false marl.
s No. 30, Buggy, below Buggy false marl.
t No. 31, Buggy, below Buggy false marl.
u No. 32, Buggy, below Buggy false marl.

In many of these localities the potassium bearing deposits are too small to be of any commercial value. The most important are e, f, i, m, n, s and u. Of these e, i and m are probably exposures of one seam. i and m both underlie the highest of a series of marl beds separating the Pharwala and Sujowal salt seams, the deposits above these being good salt; e, however, is overlain by a series not nearly so pure, which inclines Mr. Reid, the mines superintendent, to doubt my contention that this exposure belongs to the same bed as i and m. When the positions of the three exposures, however, are plotted in three dimensions, there appear to be good grounds for believing them identical. The plane, which the three points form, dips at about 50° N.-W. The observed dip at i is 25°, at m 25° and at e about 55°, all approximately N. 30° W. The calculated dip therefore is no far from what one would expect if the exposures belonged to the same seam. There is a further justification in that the bed at e is at a true distance of about 50 metres above another potassium bearing seam f; the bed m, with which it is presumed that e corresponds, and which is certainly the same as i, is likewise at a true distance of about 50 metres above a potassium bearing seam n of the same thickness as f. The presumption, then, although not proved, is probably sound, that e, i and m are parts of the same stratum, which we may call the Sujowal-Pharwala seam, and that f and n form parts of another, which we may call the Pharwala saem. The

third occurrence of any importance, which may be called the Buggy seam, extends from q to u and is easily traceable.

Average samples[1] taken across the seams e, i, m, n and u contained the following percentages of K_2O.

Seam.	True thickness.	K_2O
	Metres.	Per cent.
e	1·98	6·8
i	1·17	9·6
m	1·22	8·0
n	2·44	7·7
u	0·69	14·4

With the data available it is impossible to estimate the quantities of potassium salts which these exposures represent, but one can form a rough idea of their order of magnitude. In addition to the exposures at e, i and m, the Sujowal-Pharwala seam is found at c, where it is about 0·5 metre thick, and at d, where it is thinning out from a thickness of 1 metre. The exposure at d, 0·4 metre, is probably the same bed and it is found again at p, 0·2 metre in thickness. These data show that the seam decreases in thickness as it is followed up the rise, so we shall leave out of consideration exposures higher than i. i is at a distance of about 53 metres N.-N.-W. from the line joining e and m, whose distance apart is 220 metres. The thickness of the bed is 1·98 metres at e, 1·17 metres at i, and 1·22 metres at m. If we take the average of these (1·46) as the mean thickness of the seam, assume that the deposit extends to i with the breadth which it has between e and m, and take its specific gravity as 2·3, it would contain about 40,000 metric tons, carrying, say 3,000 tons of K_2O. The figures are probably underestimates, for, although the bed thins out on the rise, it probably increases in thickness with depth, the lowest exposure, c, being also the thickest. What has been called the Pharwala seam has been met with only at two points, f and n, about 220 metres apart, both in low level exploring

[1] A convenient method of taking samples in such material without much loss is to have a large sheet, held up at the four corners, and with a hole in the middle of it fitting round the waist of the man who cuts with a pick the uniform niche from hanging to foot wall.

drifts; as it is not even certain that they belong to the same bed, it might be unwise to do more than point out the favourable indications they afford. That at f is 2·4 metres thick; that at m is also 2·4 metres thick, and carries 8·0 per cent. of K_2O. The Buggy seam at s is 0·95 metres in thickness, and at u, about 45 metres distant, it is 0·61 metres. The deposit thins out as it is traced up the rise, the lowest exposure, s, being the thickest. At r. for instance, whose line of strike is some 60 metres up the rise from that of s, it is only a few centimetres. The quantity of the deposit in sight. therefore, is not more than a few hundred tons. No excavation further down the dip had been made at the time of my visit, and the basin of deposition may, of course, be deeper at other parts.

A potash bed was found in the small mine in the magnificent gorge of Nilawan about 3 km. S.-S.-E. of the village of Nurpur, from which it derives its name, and 18 km. from the railway at Lilla, whither the rock salt is transported on camels. The situation of the seam, which is exposed only in one place at the head of a somewhat inaccessible drift, is not easily described, but is shown in the rough sketch, Fig. 12. taken mainly from the mine plans. It strikes N. 10° E. and has a south-easterly dip of about 75°. A boring was made through the seam and its true thickness ascertained to be about 1·9 metres. The material from the borehole was carefully collected and may be taken as nearly approaching an average sample. It contained 13·6 per cent. of K_2O.

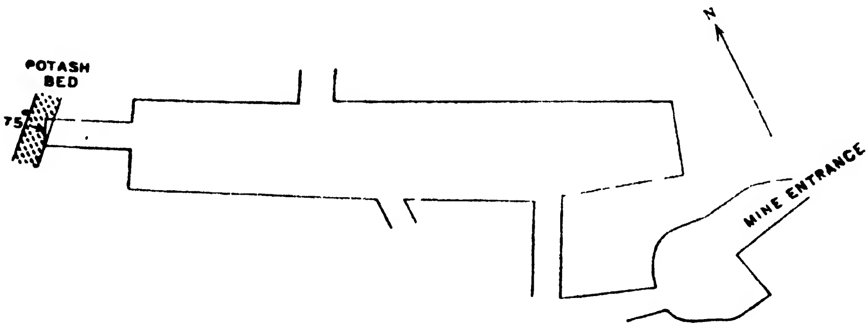

FIG. 12.

The deposits are all very similar in general character; they contain common salt, kieserite ($MgSO_4,H_2O$), langbeinite (K_2SO_4, $2MgSO_4$), sylvite (KCl) and kainite (KCl, $MgSO_4$, $3H_2O$). Analyses

of average samples from the Pharwala-Sujowal, Buggy, and Nurpur seams are given below.

—	Pharwala-Sujowal.	Buggy.	Nurpur.
K	8·0	11·9	11·3
Na (calculated)	21·5	10·0	9·2
Mg	4·8	8·9	9·0
Cl	37·5	23·3	21·4
SO_4	22·9	39·3	39·5
H_2O	4·9	7·1	9·3
	99·6	100·5	99·7

The difficulties of obtaining pure potassium salts from such mixtures are considerable, and they differ in mineralogical composition so markedly from the salts usually mined in Europe that analogous methods of treatment are inapplicable. Crystallisation from aqueous solution at any temperature is not likely to be feasible. Were magnesium chloride ever available, the method of W. Feit[1], by which the material is treated with a hot saturated solution of salt with a sufficient quantity of magnesium chloride to prevent the solution of magnesium sulphate, might be employed, but in the present circumstances it would probably be preferable to remove the magnesium sulphate with lime ($MgSO_4 + Ca(OH)_2 — Mg(OH)_2 + CaSO_4$), limestone and coal of a quality good enough for burning purposes being readily available in the neighbourhood. The operations would comprise the solution of the raw material, preferably with the help of hot mother liquors, the addition of a slight excess of slaked lime of the consistency of a thin cream, the agitation of the mixture until the precipitation of the magnesium hydroxide was complete, and the filtration of the soluble portion, now consisting of chlorides and sulphates of sodium and potassium, from the insoluble calcium sulphate and magnesium hydroxide. The filtrate would then be concentrated at boiling temperature until saturated, allowed to cool and the mother liquor drained away from the crystalline product formed, the latter being subsequently recrystallised. It is of course dangerous to draw conclusions from laboratory tests as to what would occur when the same reactions are carried out on an industrial scale, but it may be recorded that from a solution

[1] *Kali,* *3* (1909), 313.

in water of 150 g. of a sample from the Nurpur seam, the analysis of which is given below in the first column, 20·0 g. of the product whose composition, when dried, is shown in the second column, was obtained on cooling to 10° C. the boiling saturated solution, freed as above from magnesium salts.

—	Raw material.	Concentrate.
K	11·3	44·7
Na	9·2	4·3
Mg	9·0	trace.
Cl	21·4	35·6
SO_4	39·5	15·5
H_2O	9·3	trace.
	99·7	100·1

This, it is true, represents a recovery of but 53 per cent. of the total potassium in the raw material, but by judicious use for dissolving purposes of the mother liquors obtained on crystallising, the yield could probably be increased. The mining costs would be comparatively low; they would, however, considerably exceed the Re. 1-13 per ton expended on recovery of the more easily mined rock salt. It is difficult to estimate the value of the products that would be recovered. High grade potassium sulphate is sold in Calcutta at about Rs. 200 per ton, say Rs. 90 per ton of K, so that were the extensiveness of any of the seams definitely proved, there would appear to be an ample margin for extraction and freight charges.

The potassium deposits found are usually regularly interbedded between a lower seam of rock salt and an upper one of marl, consisting of highly impure ferruginous salt with clayey material, grains of quartz and often, at least in the lower portions, kieserite. Occasionally, however, as in the Sujowal-Pharwala seam in No. 12 drift, the deposit is underlain by a marl seam and succeeded above by rock salt. The deposits are usually fairly constant in thickness; where a seam thins out, it usually does so gradually. The various minerals in the deposits occur promiscuously and are not regularly interbedded among themselves; sometimes pockets of nearly pure langbeinite, sylvite and kieserite occur, but as a rule the minerals are associated with common salt in a coarse-grained aggregate. The kieserite is usually in opaque, white masses, whose exposed

surface is usually covered with an efflorescent coating of epsomite ($MgSO_4,7H_2O$). The sylvite is usually semi-transparent and of an orange-red colour, but water clear specimens are fairly common. The langbeinite occasionally occurs as perfectly transparent, colourless aggregates, with pronounced conchoidal fracture, but more usually it is present in opaque, white masses, generally white, but frequently tinged with blue[1]. Kainite, a mineral which has not previously been reported from India, is seldom clear, appearing as white to pink, translucent or opaque patches. Although of frequent occurrence it very rarely occurs pure. The following analyses was made on a specimen from the Pharwala-Sujowal seam in No. 22 drift, which weighed only 0·1079 g., but was the purest specimen obtainable. Its specific gravity was 2·126 at 29°C. Under the microscope it appeared homogeneous except for the presence of a thin streak of salt and minute inclusions of an anisotropic mineral not in the same optical orientation, probably kieserite. The refractive index of the flake was slightly less than 1·50, its optical charcter negative. The theoretical composition of kainite ($KCl, MgSO_4. 3H_2O$) is given in column 2.

—	1	2
K	15·8	15·7
Mg	9·6	9·8
Cl	15·1	14·2
SO_4	38·5	38·6
H_2O	undetermined	21·7
		100·00

Epsomite ($MgSO_4,7H_2O$) occurs frequently as an efflorescence on exposed kieserite; and traces of mirabilite ($Na_2SO_4,10H_2O$) are also found. Blödite ($Na_2SO_4, MgSO_4,4H_2O$)[2] of which a seam occurs at the crest of a small anticline in No. 29 Buggy, where the Buggy potassium seam is pinching out, is very sparingly represented in the potassium seams examined.

Plate 25, illustrating a specimen from the Pharwala seam in No. 22 drift and Plate 28, giving the results of a mineralogical

[1] Analyses of langbeinite from the Mayo mines are given by F. R. Mallet, *Mineral Mag., 12* (1900), 163.

[2] *Cf.* C. S. Fox, Note on specimens of blödite from the Salt Range, *Rec. Geol. Surv., Ind., 42* (1912), 34.

analysis of a section across the Buggy seam in block 30, are typical of the irregular way in which the various minerals are associated. For the mineralogical investigation[1] samples at short intervals were ground in a coffee mill, and 5 g. of the material, which had passed through a sieve with 12 meshes per centimetre and been retained by one with 16 meshes, were treated in a Penfield separator with a mixture of acetylene tetrabromide and toluene of specific gravity 2·00. The separated portions were washed with toluene, dried at 45° C., and the heavier separated with a similar mixture of specific gravity 2·30. The heaviest portion was again separated with a liquid of specific gravity 2·70. The washed and dried fractions were weighed and their composition determined microscopically. The most convenient method of discrimination is by determination of the refractive index. The immersion method of Schröeder van der Kolk was used, with the series of liquids and the modifications of the method recommended by F. E. Wright[2], and the data given by R. Gorgey[3]. The extent of the double refraction, the optical character and, in doubtful cases, micro-chemical reactions were used for confirmatory purposes.

The method has the advantage of greater certainty of identification than can be attained by a petrological examination of thin sections, but the latter is necessary to show the inter-relationships of the various minerals. The preparation of such sections is a matter of some little difficulty, as the character of some of the minerals with water of crystallisation is completely changed on heating. The technique found to be most convenient was to grind the specimen with carborundum and thick lubricating oil, using a bath of kerosene oil for washing purposes and finishing with an oilstone and lubricating oil. A slide was prepared with well-cooked Canada balsam and, while the balsam was still hot and liquid, placed quickly on a flat piece of wood floating on a bath of mercury. The polished surface of the specimen was then placed on the slide and the whole immediately depressed beneath the surface of the mercury. The other side of the specimen was then ground and polished as before, using kerosene oil sparingly for washing; the section was not removed from the slide, but mounted, cold, with Canada balsam and kept in a horizontal position until set. In the slides each of

[1] *Cf.* O. Riedel, *Zeitschr. Kryst. Min.*, *50* (1912), 139.
[2] "The Methods of Petrographic-Microscopic Research," p. 97; Washington, 1911
[3] *Min. pet. Mitth.* *29* (1910), 192.

the minerals, salt, sylvite, langbeinite, kieserite and kainite has been found in intimate association with the others, and all would seem to have crystallised simultaneously.

The Origin of the Salt Marl.

The origin of the Salt Marl, which usually underlies the Cambrian Purple Sandstone series, has long been the subject of controversy. An apology would perhaps be necessary for advocating an obvious and straightforward sedimentary theory of its origin, such as is outlined below, were it not that the igneous hypothesis first adumbrated sixty years ago has been supported by many distinguished geologists, and is still the view accepted by many of those best qualified to judge.

The first attempt to explain the origin of the Salt Marl was made by A. Fleming[1], who summarised as follows his reasons for considering it as being of an eruptive character :—

"(1) Because it presents no traces, or at most such as are very imperfect, of stratification.

(2) Because it contains angular masses of other rocks of the salt range.

(3) Because the gypsum and salt are for the most part found in large and small masses at irregular depths in the marl, being evidently portions of what originally has been a regular bed.

(4) The gypsum is in some cases reduced to a white powdery rock, as if it were burned, and in and on the surface of the marl are formed fragments of a trappean rock, sometimes containing nests of talc, which I believe to be altered sandstone or clay. This trappean rock I have found nowhere in a dyke or bed, only in fragments of the marl, or in small detached lumps on its surface.

(5) The red sandstone near the salt-marl is very much rent and broken, and where the salt-marl crops out there is a most extraordinary disturbance in the strata superior to it. It very often appears in valleys, filling these up, in a manner, while the strata dip from either side."

[1] Letter to R. I. Murchison, *Quar. Jour. Geol. Soc.* 9 (1853), 197.

In his subsequent report to the Government of India[1], however, he abandoned the idea of an igneous origin on account of the distinct proofs of stratification which the marl presents in the western part of the Range, but still considered it probable that it had undergone metamorphism from igneous influence. H. Warth, whose local knowledge was unrivalled, took it for granted in the various papers to which reference has been made, that the deposits are sedimentary in character, a conclusion with which W. T. Blanford[2] was in full agreement. A. B. Wynne[3], in his memoir on the geology of the Salt Range, fought shy of any definite pronouncement; "the regularity with which the red marl, salt, and gypsum are overlaid by aqueous deposits, together with their internal stratification so far as this is exhibited, are in favour of the salt having been produced by evaporation;" on the other hand, association with the Khewra trap, "the suggestion of high temperature indicated by the semi-anhydrite," "the enormous quantity of sea-water necessary for the formation of so much salt and the absence of ordinary detrital stratified deposits formed in that sea" inclined him towards a hypogenic explanation.

C. S. Middlemiss[4] has ably marshalled the arguments in favour of the igneous hypothesis. To the negative evidence in the absence of organic remains, of stratification, colour banding or any other signs of sedimentation, he added a number of new observations supporting his view. The dolomite included in the Salt Marl is often honeycombed by corrosion and anastomosed with strings of gypsum, as if it had been converted into a gypseous marl by metamorphic agencies. There is no satisfactory evidence for the passage, described by A. B. Wynne, of the Red Marl into the Purple Sandstone overlying it, no true inter-bedding, but merely a brecciated junction. A series of sections is illustrated and described showing the Red Marl in positions unexplainable by any system of faulting, forming the cores of flexures and occupying lines of fracture generally, in fact, "showing that the Red Marl must have possessed a plasticity, and a power of movement, subsequent to the deposition of many of the formations above it." On this and corroborative evidence supplied by P. N. Datta he was led to ask—

[1] *Jour. As. Soc. Beng.*, *22* (1854), 241.
[2] Manual of the Geology of India, Part 2, 488, Calcutta (1878).
[3] *Mem. Geol. Surv., Ind.*, *14* (1878), 82.
[4] *Rec. Geol. Surv. Ind.*, *24* (1891), 26-42.

"Can we see in it anything of the nature of a scum, such as we might picture to ourselves as having partly secreted at the surface of an ancient untapped magma, and partly resulted from that secretion by induced changes in the overlying dolomitic strata? If we can, we have but to give the substance a gently intrusive or injective impetus, followed by consolidation, some time during the Tertiary period, to account for all the otherwise perplexing circumstances under which the salt-bearing beds of the Punjab are found."

The theory was supported by T. H. Holland[1], whose examination of the quartz crystals found in the Salt Marl showed them to contain anhydrite; this he interpreted as precluding the possibility of their having been deposited from water at ordinary temperatures. His suggestion that the anhydrite might have been produced by the action of sulphuric acid on limestone at a high temperature and in the presence of superheated waters was adopted by R. D. Oldham.[2] F. Noetling[3] and E. Vredenburg[4] have also lent their support to Middlemiss' theory.

The chief arguments in favour of the igneous origin of the formation may be summarised as follows:—

(1) The absence of signs of sedimentation.
(2) The brecciated passage into the formation above.
(3) The absence of organic remains.
(4) The metamorphism of the gypsum and dolomite it contains.
(5) Its association with the Khewra trap.
(6) Its frequently anomalous situation.
(7) The presence of anhydrite.

Let us consider them *seriatim*.

(1) A rock containing as much soluble matter as the Salt Marl is very easily affected by weathering agencies, and it seems not improbable that signs of stratification should have been obliterated by the solvent action of water on the contained salt and gypsum at some depth from the surface, and the rearrangement of the residual plastic, clayey material before its exposure. When one penetrates, as one can in the salt mines, beyond the zone of surface weathering, evidence of stratification is by no means wanting. The purer salt

[1] *Rec. Geol., Surv. Ind., 24* (1891), 231.
[2] Manual of Indian Geology, 2nd Edition, 112, Calcutta, 1893.
[3] *Rec. Geol. Surv Ind., 27* (1894), 74
[4] "A Summary of the Geology of India." 2nd ed., 105, Calcutta, 1910.

seams are separated from one another by reddish bands of "kallar," or salt with earthy impurities, and these can often be traced, with a fairly constant strike and dip, for hundreds of feet. The stratification can be seen in the photograph reproduced as Plate 26, taken in the Mayo mine at Khewra. The potassium-bearing beds also can be traced at definite horizons from chamber to chamber.

(2) The absence of any true passage upwards into the Purple Sandstone formation may be due to the same agencies which have removed the signs of stratification at the surface; after heavy rain the exposed Red Marl acquires the consistency of viscous mud into which detached masses of the overlying sandstone may sink, thus giving rise, on the consolidation of the whole, to a brecciated junction.

(3) No definite evidence is available for the determination of the age of the Salt Marl. It might possibly antedate the earliest fossiliferous epochs, for it generally underlies the Cambrian rocks of the Range; but such a conclusion is by no means necessary. Salt deposits in general, whatever their age or origin, are singularly unfossiliferous. Whether it be that the fauna of the original sea, sensitive, as most marine organisms are, to slight alteration in density, migrated to the fresher water which might be supposed, on the theory of Ochsenius, to flow in across the ocean barrier; whether in the event of the barrier being impassable, the organisms, unable to accommodate themselves sufficiently rapidly to an increasing salinity, either died out and were buried in the lowermost strata, or rose to the surface of the denser water, there to be completely decomposed by atmospheric agencies—perhaps giving rise to those indications of oil, which are so frequently associated (the Salt Range is no exception) with salt deposits: whatever be the true explanation, the fact of the general absence of fossils from sedimentary salt deposits is indisputable, and the argument, therefore, need not concern us further.

(4) According to F. W. Pfaff[1] dolomite, gypsum and salt frequently occur together. A detailed description of their association in a salt deposit has been given by T. Sterry Hunt[2] in an account of the results of a deep boring in the Goderich salt region of Ontario. There limestone, with corals and beds of dolomite, is succeeded lower down by alternating seams of dolomite, rock salt, anhydrite and "marl." Before reaching the purer salt strata the drill was fed

[1] *Neues Jahrb. f. Min. etc.*, 9, Beilageband (1894-95), 487.
[2] Geol. Surv. Canada, Report of Progress for 1876-77 (1878), 226-243.

with water, and the description of the dolomite cores so obtained tallies so closely with the appearance of the specimens described by Middlemiss, that it is given *verbatim*.

> "These dolomites are in some parts fine-grained and compact, and other parts coarsely granular and crystalline. In many beds the cut surface of the compact rock, as seen in the cores, is marked by numerous small, round, shallow pits, from one to two-tenths of an inch in diameter, apparently formed by the dissolving-out of some substance. These give the rock a worm-eaten aspect, which led the late Prof. Eaton to call similar beds, belonging to the same geological horizon in the State of New York, *vermicular lime-rock*. In other beds the surface of the cores is marked from the removal, by solution, of thin-bladed crystals, which give rise to what appear like small gashes or incisions in the compact rock. These are sometimes half-an-inch in length, and occasionally intersect each other at right angles. Some portions of the rock are porous or cellular throughout, and in other parts the mass is made up of thin curved or waved laminae, alternating of lighter and darker colours."

On reaching the first bed of rock salt the drill was supplied with saturated brine, and the dolomite cores subsequently obtained held irregular masses of salt in frequent veins and sometimes layers of anhydrite. The presumption, then, that the honeycomb structure in the dolomite is due to solution of its soluble constituents is not far-fetched. The formation would appear to be of undoubted sedimentary origin[1] and the explanation, therefore, may reasonably be applied to the peculiar features of the dolomite of the Salt Marl. The gypsum; as we shall see (p. 261) is a secondary deposit, and the reason for its corrosion is not far to seek.

(5) The trap-like rock, which is frequently exposed in the Salt Marl, has not yet been met with in the mines, and, as it is always very badly weathered and in material which is probably detrital, the relationship of the two rocks is obscured. It has probably been intruded into the Salt Marl. Similar basaltic intrusions have been met with in the (sedimentary) salt deposits of Hanover[2] and Saxe-Meiningen.[3]

[1] *Ibid.*, 242.
[2] E. Harbort, *Zeitschr. Deutsch. geol. Gesell.*, (Monatsber.) *62* (1910), 340.
[3] E. Naumann, *ibid.*, 343.

(6) The strongest argument in favour of a hypogene origin lies in the frequently anomalous situation of the beds with respect to the formation which they usually underlie. There can be no doubt of the quasi-intrusive character of the Salt Marl in the many sections which Middlemiss[1] has described, but the intrusion does not necessarily imply a state of igneous fusion. Anomalies of this character are not uncommon in connection with rock-salt deposits. Their occurrence in Northern Germany has been described in great detail, and other examples may be cited from Algeria[2] and Louisiana.[3] Broadly speaking, three types of theory have been advanced to explain them: volcanic, whereby the salt has been intruded in a fused condition, tectonic, the structures being due to ordinary earth movements, and "autoplastic"[4] or endogenetic--due to an inherent power of movement in the deposit itself. A summary of the older volcanic theories, now generally abandoned[5], is given by R. Lachmann.[6] The purely tectonic theory has been stated for the North German deposits by A. von Koenen[7] and H. Everding[8], and upheld by (among many others) H. Stille[9] and, although not in its entirety, by E. Harbort.[10] The third theory has suffered from an indefiniteness either in conception or expression, and it is largely owing to this that its discussion has given rise to a highly polemical controversy, chiefly with regard to its application to the phenomena of the German salt deposits. Many attempts have been made to explain the peculiar dome-shaped structure of rock-salt occurrences in Louisiana and East Texas, which have been described in detail by G. D Harris.[11] A. F. Lucas[12] suggested that the domes were due to gas pressure, R. T. Hill[13] that they were caused by the hydrostatic pressure of hot saturated brine ascending along lines of weakness, while L. Hager[14] surmised that they were formed by intrusive laccoliths generating gases and heated solutions. G. D.

[1] *Loc. cit.*, 31-40, sketch sections 3-13, plates 3 and 4.

[2] *Cf.* L. Ville, *Ann. des Mines*, 5th Ser., *15* (1859), 351.

[3] *Cf.* G. D. Harris, Geol Surv. Louisiana, *Bull. 7* (1908), 59.

[4] R. Lachmann, *Zeitschr. Deutsch. geol. Gesell.* (Monatsber.), *62* (1910), 113.

[5] *Cf.*, however, E. Coste, *Jour. Canadian Mining Inst. 6* (1903), 73 and L. Hager, *Eng. and Min. Jour.*, *78* (1964), 182.

[6] *Kali*, *4* (1910), 161 and "Der Salzauftrieb," p. 5; Halle, 1911.

[7] *Zeitschr. prakt. Geologie*, *13* (1905), 157.

[8] "Deutschlands Kalibergbau," Zur Geologie der Deutschen Zechsteinsalze, p. 50; Berlin, 1907.

[9] *Zeitschr. prakt. Geologie*, *19* (1911), 91 and *Kali*, *5* (1911), 341 and 365.

[10] *Zeitschr. Deutsch. geol. Gesell.* (Monatsber.), *62*, (1910), 326; *Kali*, *7* (1913), 112.

[11] Geol. Surv. Louisiana, *Bull. 7* (1908), and *Econ. Geology*, *4* (1909), 12.

[12] *Science*, *14* (1901), 327, quoted by Harris.

[13] *Jour. Franklin Inst.*, 3rd Ser., *154* (1902), 273.

[14] *Eng. and Min. Jour.*, *78* (1904), 182.

Harris[1] put forward an endogenetic theory that the uplifting force for the formation of the quaquaversal structure of the domes was due to "the power of growing crystals," demonstrated for alum and other crystalline substances by G. F. Becker and A. L. Day[2], and that the presence of the salt was due to its precipitation, by a decrease in temperature, from rising columns of hot brine. R. Lachmann[3], in a long series of articles, has insisted on the purely endogenous origin of such "eczematous" structures (Salzekzeme), the cause of their upheaval being found in the group of osmotic forces (die Gruppe der osmotischen Kräfte)[4] in recrystallisation and in metathetical changes by solution (Lösungsumsatz).[5] The adequacy of these agencies to bring about the phenomena observed has been questioned by K. Andrée[6], E. Harbort[7], E. Seidl[8] and others. Lachmann submitted the problem to S. Arrhenius[9], whose explanation is definite and simple. Arrhenius considers that the vertical force necessary to account for the anomalous structures is none other than that of gravity, the phenomena observed being a simple case of isostasy. Salt has been shown by F. Rinne[10] to be plastic under pressure, its specific gravity (2·16) is usually less than that of the rocks it underlies, and as a consequence it is squeezed upwards along lines of weakness. The controversy would appear to have been settled with this reasonable explanation, which may also be applied to such anomalous structures in the Salt Range as cannot adequately be explained by direct analogy with the results of tectonic forces on less plastic formations. The subordinate question of the movements in the Salt Marl due to volume changes in the salts themselves is noticed on p. 263.

(7) The presumption that the presence of calcium sulphate in its anhydrous form, as it was found by T. H. Holland[11] in quartz

[1] *Loc. cit.*
[2] *Proc. Washington Acad. Sci.*, *7* (1905), 283.
[3] *Zeitschr. Deutsch. geol. Gesell.* (Monatsber.), *62* (1910), 113; *63* (1911), 491. *Kali*, *4* (1910), 161 and 477; *6* (1912), 342. "Der Salzauftrieb," erste und zweite Folge, Halle, 1911; dritte Folge, Halle, 1912. *Centralbl. Min., Geol. u. Pal.*, 1911, 534; 1912, 745.
[4] *Zeitschr. Deutsch. geol. Gesell.* (Monatsber.), *63* (1911), 491.
[5] *Kali*, *6* (1912), 352.
[6] *Centralbl. Min. Geol. u. Pal.*, 1911, 698; 1912, 129.
[7] *Zeitschr. Deutsch. geol. Gesell.* (Monatsber.), *63* (1911), 267, *65* (1913), 101.
[8] *Ibid.* (*Abhandl.*), *65* (1913), 148.
[9] *Kali*, *6* (1912), 361; *Meddelanden K. Vet. Akad. Nobelinstitut*, *2*. (1912), No. 20. *Cf.* also E. Harbort, *Zeitschr. Deutsch. geol. Gezell.* (Monatsber.), *63* (1911), 271.
[10] *Neues Jahrb. f. Min., etc.*, 1904, *1*, 114.
[11] *Loc. cit.* Quartz crystals with inclusions of anhydrite have also been described from the salt deposits of the Pyrenees. Beaugey, *Bull. Soc. fran. Min.*, *12*. (1889), 396.

crystals from the Salt Marl, indicates a high temperature of origin is not justified. R. Brauns[1] in 1894 showed that calcium sulphate could be deposited at ordinary temperatures as anhydrite from a concentrated solution containing sodium, potassium and magnesium chlorides, and the subject has since been studied in great detail by J. H. van't Hoff and his collaborators. Their results[2] show that, at any rate from 25°C. upwards, calcium sulphate is precipitated as anhydrite and not as gypsum from solutions corresponding in composition with concentrated sea-water, and saturated with respect to sodium chloride and calcium sulphate.

The task of destructive criticism having been completed, an attempt may now be made to suggest a feasible explanation of the way in which the Salt Marl assumed its present form. The well-known theory of G. Bischof[3] and C. Ochsenius[4] will serve as a basis, for its only serious rival, that of J. Walther,[5] less adequately explains the extent and purity of deposits such as are met with in the rock-salt mines of the Range.

We imagine, then, an arm of the ocean almost completely shut off from it by a bar, over which sea water might enter to compensate for the heavy losses by evaporation which arid climatic conditions entail. When the brine inside the bar had become saturated, precipitation of its various salts would proceed in the order worked out by van't Hoff and his co-workers[6]; calcium sulphate would form the lowermost deposits, and after the greater part of the sodium chloride had been precipitated, we may imagine the bar to have reached such an elevation that communication with the ocean was temporarily interrupted. In the shallow brine lake which was left crystallisation would not necessarily proceed uniformly, but the mother liquors would accumulate in the lower basins of the region, there depositing their potassium and magnesium salts and giving rise to lenticular beds such as we find in the Buggy section of the Khewra mines. Most of the occurrences in the Salt Range

[1] *Neues Jahrb. f. Min. etc.*, 1894, *2*, 257.
[2] J. H. van't Hoff and F. Weigert, *Sitzungsb. Akad. Berlin*, 1901, 1148.
[3] "Lehrbuch der chemischen und physikalischen Geologie," 2nd ed., *2*, 48½; Bonn, 1864.
[4] *Proc. Acad. Nat. Sci. Philadelphia*, 1888, 181.
[5] "Das Gesetz der Wustenbildung," 2nd ed., Leipzig, 1912. The points of difference between the two theories are discussed in *Centralbl. Min., Geol. u. Pal.*, 1902, 551 and 620; 1903, 211.
[6] "Untersuchungen über die Bildungsverhältnisse der ozeanischen Salzablagerungen;" Leipzig, 1912.

are overlain by a layer of "kallar," often containing kieserite, but consisting chiefly of salt, with calcium sulphate, impalpable ferruginous clay and innumerable quartz grains, of all sizes up to about 0·2 mm., and almost all highly angular in outline. Such deposits were probably wind-borne and helped to protect the very soluble salts below from being dissolved, when a fresh influx of water took place. There are examples, however, where beds of potassium salts are succeeded by comparatively pure rock-salt. It may be supposed that the accession of ocean water over the bar was a gradual one, and that by the time it reached the lagoons from which potassium salts had been deposited, it had already dissolved as much *en route* as to make it sufficiently nearly saturated to act as a protection to the beds below. No layers of anhydrite are found overlying the potassium-bearing beds, such as we might expect had a catastrophic influx of ocean water taken place; the "kallar" seams above, however, contain considerable quantities of calcium sulphate, as do also the overlying salt beds. The accumulations of gypsum, which, with red clay, form characteristic features of the Salt Marl in most of the places where it is exposed, may be due to deposition from a later large influx of ocean water into the sinking depression, but it seems more probable that they were formed later, in the manner outlined below, as a secondary product from impure rock-salt.

After the close of the saline period, perhaps by submergence and renewed connection with the open sea, other sediments were superposed before the solvent action of the sea water could obliterate the earlier deposits. It is not the purpose of this note to discuss what these sediments were,- whether the Purple Sandstone now overlying the Salt Marl was then deposited, or whether it was thrust over the latter, as T. H. Holland[1] and others have suggested. In order, however, to explain the mutual association of the minerals contained in the potassium-bearing beds, we shall assume that at some epoch they were covered by such a thickness[2] of strata, or subjected by pressure to such a frictional movement as would raise their temperature to the neighbourhood of 80°C and effect the metamorphosis of the potash beds described on p. 263.

The anomalous stratigraphical relationships existing between the Salt Marl and other formations of the Range may be explained

[1] "Imperial Gazetteer of India" I, 64; Oxford, 1907.
[2] Some 1,500 to 2,000 metres.

as due largely to isostatic adjustment of the salt deposits, which the pressure of superincumbent strata had rendered plastic. Taking a purely hypothetical example, a column of Purple Sandstone of specific gravity 2·29, 50 metres deep, succeeded by a column of Magnesian Sandstone, of specific gravity 2·51 and the same cross section and depth, would be able to balance a column of rock-salt (assuming complete plasticity) of specific gravity 2·16 and similar cross section, 111 metres deep[1] or would be able to thurst it 11 metres higher than its own surface. It is not suggested that this has been the only influence at work; the Salt Marl has of course been involved in ordinary tectonic movements that have affected other formations, and its plasticity has probably tended to make its participation more complete than that of a more rigid series. There are, too, the effect of change of volume in the salts themselves, such as are noticed on p. 263, and more particularly the alteration of anhydrite to gypsum, involving an increase in volume of 60 per cent. Nor must we forget minor disturbances which one would expect to be caused in a rock with the properties possessed by the Salt Marl. When its more soluble matter had been removed by percolating waters, not only would the rock mass be less able to withstand pressure from any direction, but the more insoluble constituents would be left—as they become now after heavy rain—in the condition of a semi-fluid mud plastic enough to be squeezed into almost any position.

The result of all those agencies has been to force the Salt Marl between surfaces of fracture, into the cores of flexures and along similar lines of weakness. Equilibrium would, however, quickly be disturbed by solution of the common salt on exposure at the surface. A further uplift would take place when the weight of this material had been removed, and equilibrium would only be established when detrital material, 'consisting of the insoluble constituents of the formation, had been accumulated to an extent sufficient to protect the salt beneath from further surface weathering. The gypsum and red clay which form the surface features of the Salt Marl probably represent these accumulations, having been derived from the comparatively insignificant amount of insoluble matter contained in the rock-salt and "kallar" seams. An example of the nature and amount of these insoluble impurities is given in the following

[1] $(100 \times \frac{2\cdot29+2\cdot51}{2} -)$ 12·16.

analysis, by C. Hickie[1], of "bad salt, which is thrown away as waste from the Soojewal Depôt."

Earthy matter	1·10	per cent.
$CaSO_4$	2·50	„
$MgSO_4$	1·00	„
$MgCl_2$	0·83	„
$NaCl$	93·41	„
H_2O and loss	1·16	„
	100·00	„

Were the gypsum thus derived, it would not improbably have the sponge-like or kneaded appearance it so frequently presents. Dolomite has not yet been met with in the salt mines of the Range. The necessary conditions for its formation in nature are still somewhat obscure[2], but, as seams of it are often associated with salt deposits, its occurrence among the insoluble residues of the Salt Marl is not surprising. An explanation of its appearance has already been given on p. 256.

A chapter in the geological history of the Salt Marl is supplied by the evidence of the potassium-bearing beds. Van't Hoff has shown that the simultaneous occurrence of rock-salt, langbeinite, sylvite, kieserite and kainite is possible only when crystallisation from solution has taken place at about 80°C :[3], a temperature which *a priori* is improbable under surface conditions as we now know them. It is possible that the climate of the epoch in which the Salt Marl was laid down was much hotter than it is now, and that such temperatures were attainable in shallow basins under a scorching sun. Indeed A. v. Kaleczinsky[4] has shown that in the Medve salt lake in Hungary temperatures up to 63° C. are attainable at some depth from the surface, and his data are often quoted in support of the theories of a high temperature of deposition for some of the European deposits. Kaleczinsky shows, however, in the same paper that such heat concentration is only possible when a zone of comparatively fresh water is resting on more concentrated solutions, — a condition pre-

[1] Report on the Administration of the Inland Customs Department for 1869-70, App. H, p. 178, Calcutta ; 1870.

[2] *Resumés* of the extensive work done on this subject, with full references, are given by F. W. Clarke, "The Data of Geochemistry," 2nd ed., *Bull. U. S. Geol. Surv.*, *491*, (1911), 535, and H. Leitmeier in C. Doelter's "Handbuch der Mineralchemie," I, 396 Leipzig, 1912.

[3] "Zur Bildung der ozeanischen Salzablagerungen" I, 57 ; Brunswick, 1905.

[4] Foldtoni Kozlony, *3*, 1901 418.

cluding precipitation—and that under the same climatic conditions a lake of uniform concentration, whether fresh or nearly saturated with salt, did not reach a temperature of 30°C. At the Sambhar Salt Lake in the Rajputana desert, one of the hottest regions of the world, the brine in the shallow " kyars " reaches a temperature of only 39°C. in the hottest period of the year[1]. From present analogies then, we would not be justified in assuming such a high temperature as 80° for the original deposition of the potash-bearing salts, and it seems more probable that they were laid down at lower temperatures and afterwards thermally metamorphosed to their present condition. The presence of anhydrite in the quartz crystals of the Salt Marl is, as we have seen (page 259), evidence in favour of a temperature of deposition of at least 25°C. If we imagine that moderate temperatures obtained such as might be expected now-a-days in an arid region, say, 30° C., precipitation from ocean mother liquors would probably give rise to a mixed deposit consisting of carnallite, KCl, $MgCl_2$, $6H_2O$, kieserite, $MgSO_4$, H_2O and kainite, KCl, $MgSO_4$, $3H_2O$, with, of course, sodium chloride. The high temperature which van't Hoff has shown to be necessary for the " paragenesis " of langbeinite, sylvite and salt (above 55°C.), of kieserite, sylvite and salt (above 72°C.), and of all four,—the presence of kainite being then no longer possible- (83°C.), may have been attained by depression of the deposits to a great depth, as S. Arrhenius[2] has suggested with reference to the occurrence of " Hartsalz " (kieserite, sylvite and salt) in the German deposits.

No data are available for the rate of the increase of temperature downwards in the neighbourhood of the Salt Range. If we consider the rate to be of average value- say, 35 metres for 1°C. rise- depression to a depth of some 1,800 metres would be sufficient for a rise of 50 C., from a surface temperature of, say, 30°. During the process of depression, and in the presence of enclosed moisture, kainite would be partly decomposed into sylvite, kieserite and water—

$$KCl, MgSO_4, 3H_2O = KCl + MgSO_4, H_2O + 2H_2O$$

giving an increase in volume of about 9 per cent. while carnallite and kieserite would form langbeinite.

$$3\ (MgSO_4,\ H_2O) + 2(KCl,\ MgCl_2\ 6\ H_2O) = K_2SO_4,\ 2MgSO_4 + 3\ MgCl_2 + 15H_2O.$$

[1] (Private communication from Mr C. H. Jeffery Orchard Assistant Commissioner, Sambhar.)

[2] *Loc. cit.*

The disappearance of the magnesium chloride presents a difficulty; it is, however, present in appreciable quantities in the overlying marl seams, and it is found too in a fissure in the continuation of the Buggy seam in chamber 29, although here its presence may be due to secondary reactions by which the associated blödite has been formed.

Evidence of the pasty character which the deposits must have assumed under pressure is given by the appearance of small folds and stringers of kieserite at the junction of the deposits with the marl seams above, as if this mineral has been squirted into the anomalous positions it occupies; an example (from the Pharwala-Sujowal seam in Drift 22) is shown in Plate 27, fig. 1. Schistose structure in the deposits, showing their mobility under pressure, is also common. An illustration of it is given in Plate 27, fig. 2, a specimen of langbeinite from the Nurpur Seam.

EXPLANATION OF PLATES.

PLATE 22.—Mayo mines hill (on the right).

PLATE 23.—Interior, Mayo mines.

PLATE 24.—Miner, Mayo Salt mine.

PLATE 25.—Specimen from the Pharwala seam, showing mineralogical composition.

PLATE 26.—Mayo Salt mine showing stratification.

PLATE 27.—Fig. 1. Kieserite in marl, overlying potash seam.
Fig. 2. Schistose structure in langbeinite.

PLATE 28.—Curves showing the proportion of different minerals in No. 30 Buggy seam.

DESCRIPTION OF TEETH REFERABLE TO THE LOWER SIWALIK CREODONT GENUS *DISSOPSALIS*, PILGRIM, BY GUY E. PILGRIM, D.SC., F.G.S., *Officiating Superintendent, Geological Survey of India.* (With Plate 29 and text figures 13 and 14.)

Previous descriptions of *Dissopsalis*.

THE genus *Dissopsalis* (of two species *D. carnifex* and *D. ruber*) was founded by me in August 1910 for the reception of certain upper teeth with Creodont affinities from the Lower Siwaliks of Chinji in the Salt Range, which were briefly described in *Records, Geol. Surv., India*, vol. XL, p. 64. Further notes on the genus were published in my Correlation of the Siwaliks with Mammal Horizons of Europe[1], when a mandible of *Hyaena*, at first provisionally referred to *Dissopsalis*, was put into its proper place. It is only now that I am at last able to figure and describe fully the material on which the new genus was established.

Creodonts previously reported to occur in the Siwaliks.

Since the Creodont character of the genus has hitherto been assumed rather than demonstrated, it will be necessary to discuss this point fully. In view of the importance which must attach to the occurrence of Creodonts at so late a period as the tortonian, which seems to be the earliest date which can be assigned to the Lower Siwalik beds in which the remains occur, it will be as well in the first instance to call attention to the fact that this was not the first occasion on which Creodonts have been authoritatively stated to occur in the Siwaliks.

Supposed *Hyaenodon*.

In 1884 Lydekker[2] figured and described a lower premolar (Ind. Mus. D. 57) from Kushalgarh on the Indus, as pm_4 of a *Hyænodon* to which he gave the specific name of *indicus*. In 1888 Schlosser[3] suggested that this tooth belonged to *Hyæna*. In 1910 the present writer[4] stated his belief that it was really the pm_3 of *Hyotherium sindiense* Lyd. Although in the Lower Siwaliks of Chinji mandibles of *Hyotherium* had been found in which pm_3 was precisely similar

[1] *Rec. Geol. Surv. Ind.*, XLIII (1913), p. 311.
[2] Siwalik and Narbada Carnivora, *Pal. Ind.*, ser. 10, II, p. 349.
[3] *Beitr. Pal. Ost. Ung.*, VI (1888), p. 195.
[4] *Rec. Geol. Surv. Ind.*, XL, p. 190, footnote.

in structure to the Kushalgarh tooth, yet the latter slightly exceeded the Chinji specimens in size. This difference in size I neglected at the time, and it was not until later, when in the stratigraphically higher beds of Nagri a mandible of *Hyotherium* came to light containing a pm_3 which agreed more nearly in size with the Kushalgarh tooth, that it seemed worth while separating it as a species distinct from the *Hyotherium* of Chinji, for which Lydekker's specific name of *indicum* is entitled to stand. The Chinji *Hyotherium* must at present be known as *Hyotherium* cf. *sindiense* Lyd. as the Sind species, which belongs to an earlier horizon, is insufficiently known to afford exact comparisons. Brief reference was made to these conclusions in my Correlation of the Siwaliks[1], while the accompanying figures of mandibles of these two species will be sufficient to justify the alteration in nomenclature.

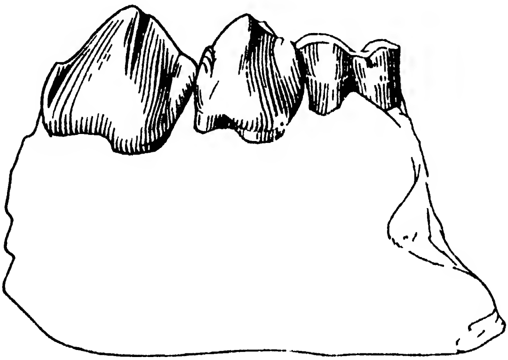

Fig. 13.—Left mandibular ramus of *Hyotherium*, cf. *sindiense* Lyd. from the Chinji beds, side view, natural size (Ind. Mus. B. 538).

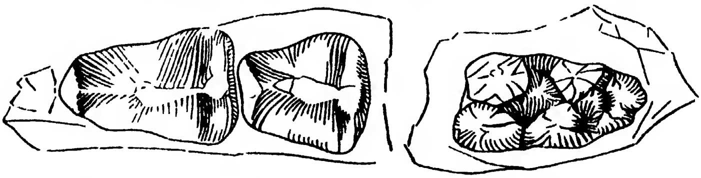

Fig. 14. —Right mandibular ramus of *Hyotherium indicum* (Lyd.) from the Nagri beds, surface view, slightly less than natural size (Ind. Mus. B. 553).

[1] l. c., pp. 317, 318, 319.

In the same place Lydekker describes and figures a fragment of a tooth as m_3 of *Hyaenodon indicum.* Schlosser pointed out that this was really a portion of an upper carnassial, which he assigned to *Amphicyon palaeindicus.* I think with Schlosser that the position of this fragment in the dentition hardly admits of any doubt, although I preferred in my brief note on the specimen[1] to refer it provisionally to *Palhyaena.*

In any case we must remove *Hyænodon* from the Siwalik fauna of India, while the occurrence of Creodonts in this fauna, in so far as it rests on the evidence which we have just considered, must be regarded as unproven. The occurrence of *Pterodon bugtiensis* Pilg. in the Bugti Hills, does not affect this, as the Bugti beds are much older than Siwalik, and belong to the Gaj series, *Pterodon bugtiensis* being probably upper aquitanian.

The specimens, locality and nature of matrix.

The specimens on which the following descriptions are based are nine in number and were all collected by Sub-Assistant Vinayak Rao from the Lower Siwaliks of Chinji. Neither the precise locality nor horizon have been recorded, but from the similar character of the matrix, which shows certain peculiar features, and the shattered condition of the bone it is evident that they were most of them obtained from the same spot probably in the lower portion of the Chinji zone. The specimens numbered D.143- D.148 are those which possess this similar matrix, which exemplifies the red, calcareous, nodular structure so common in the red clays of the Chinji beds. In the present instance it is of a specially hard and resistant nature and contains a considerable amount of crystalline calcite. This has corroded and united with the substance of the bone and enamel to such a degree that it is generally impossible to separate the two.

Type maxilla of *Dissopsalis carnifex.*

D. 143, the maxilla figured in Pl. 29, fig. 1 and the type of the species *Dissopsalis carnifex*, was in two pieces when it first came into my hands, each piece containing two teeth. Although the surfaces of junction of the pieces were by no means as clean as could be desired, yet there seemed no doubt that they were originally united. As before remarked, the specimen had been badly crushed out of shape, and portions of the individual teeth had been broken and become tightly cemented in positions quite remote from their proper ones. For example the outer cusps of the penultimate tooth, m^1, had been thrust down to a lower level and partly cemented against the

[1] *Rec. Geol. Surv. Ind.*, XL (1910), p. 65.

outer surface of the last tooth. These had to be drilled out and fixed into what appeared to be their proper place. Consequently the precise conformation of this portion of the tooth is open to doubt. The tooth next in front of this, pm^4, has also suffered. The outer cingulum has become detached and has fallen away from the base of the main cusp, while the entire inner cusp had been broken away and cemented at a much higher level than the remainder of the tooth. By removing this cusp and then very carefully cutting away the matrix close against that portion of the tooth which was still *in situ*, it became clear that a large surface of fracture existed and that the tooth must originally have been a tritubercular one. The cusp found alongside fitted the fractured surface well enough, showing that it was not an extraneous piece which had become lodged there by accident but was really the inner cusp of the tooth beside which it lay. Entire teeth agreeing precisely in structure with the restoration fortunately exist in D. 144 and D. 145, which places the matter beyond doubt. It is probable that even now, on account of insufficient cleaning, the inner cusp of this tooth is a little higher and more prominent than it ought to be.

Type maxilla of Dissopsalis ruber.

D. 147 (Pl. 29, fig. 5), the type of *Dissopsalis ruber*, is a most important fragment considered in connection with the last. The only perfect tooth it contains is a well-preserved tritubercular-sectorial tooth, which, though smaller than the last tooth of D. 143, agrees so exactly with it in general shape and proportions as to leave no doubt that its position in the mouth is the same. Not only does this tooth show details of structure which cannot be made out in the other specimen owing to its bad state of preservation, but behind it is to be seen the broken crown of another tooth, m^3, which was evidently much smaller than the preceding ones. Immediately behind this the surface of the maxilla is shown running up vertically for about 12 mm. from the base of the crown of m^3 to the point at which the jugal process may be seen to arise. It seems probable, though not absolutely certain, that the entire outline of m^3 is preserved. It is clear, therefore, that the genus possessed three molars, of which the front two were tritubercular-sectorial, the 2nd having the longer blade, a tritubercular pm^4, and in advance of this premolars devoid of an inner cusp. The presence of four premolars is only presumptive, although judging by

analogy with D. 148 (referred to *Dissopsalis ruber* but of which both specific and generic position may be different) there were three premolars in front of the tritubercular tooth. The species *D. ruber* is founded solely on the inferiority in size to *D. carnifex* although if the maxilla D. 148 (see page 273) should belong to the same, species, certain important points of difference exist in the premolars.

Other fragments.

D. 144 is an interesting specimen showing pm^3 and pm^4 which have been separated from one another and become recemented at different levels. As pm^3 in this specimen is identical in size, shape and structure with pm^3 in D. 143 it is possible that we can form a better idea of the shape of pm^4 from this than from the type.

Description of the upper dentition.

Before proceeding to discuss the affinities of these specimens, I shall first describe the upper dentition in detail, using for this purpose the type maxilla as far as possible, but amplifying the description from any of the other specimens which may happen to display better the points under consideration.

The dentition of the genus then consists of three molars and (if we may assume that of which we have no direct proof) of four premolars besides incisors and canine. M^1 is a tubercular sectorial tooth with a prominent lunate protocone, which is separated by a considerable interval from the outer cusps. This was probably very similar to the corresponding part of m^2 though the details of the former are obscured. The paracone and metacone cannot be clearly distinguished through the imperfect state of preservation. The metastyle is prolonged into a shearing blade. If the restoration of this tooth is correct, the blade of m^1 is very much shorter than that of m^2, so that the transverse very considerably exceeds the antero-posterior diameter of the tooth. M^2 is similar in structure to m^1 but the shear formed by the elongation of the metastyle is much longer, so that the antero-posterior exceeds the transverse diameter. The paracone and metacone are quite distinct though low and close together. The latter is the larger and taller, and has become partially converted into a shearing blade. The protocone is represented by a sharp-pointed cusp connected by almost imperceptible ridges to the paracone and metacone. At the base of the latter these ridges rise into two minute cusps, the paraconule and metaconule respectively. The former of these passes into a broad cingulum, which continuing round to the outside of the tooth

encircles the paracone. The metastyle forms a long shearing blade. Emphasis may be laid on the fact that many of these details of structure are only visible in m^2 of *D. ruber* and I only assume that they exist also in *D. carnifex*. Assuming (see however, p. 268), that the outline of the crown of m^3 is as we see it, it may be defined as a small tooth situated almost wholly on the inner side of m^2, and having the shape of an isosceles triangle with the apex inwards and behind and the base adjoining the shear of m^2, with which it forms a very small angle; otherwise one can form no idea as to its structure.

Pm^4 is a very stout, tritubercular tooth, whose antero-posterior slightly exceeds the transverse diameter. The contrary ratio of the two diameters, which apparently exists in pm^4 of the type maxilla, is probably due to imperfect cleaning and faulty restoration of the protocone. The conical paracone slopes very distinctly backward and is succeeded by a lower but strongly marked metacone.[1] The posterior edge of the paracone slopes forward from the summit to join this, so that the summit of the former tends to overhang the latter. The protocone is far more stoutly built than the inner cusp of the molars and consists of a rather blunt, conical cusp connected by a broad cingular ridge to the metacone and to the anterior portion of the paracone. This cingulum continues along the entire outer base of the tooth. A strong secondary cusp rises between the protocone and the metacone. This is visible in D. 145 (Pl. 29, fig. 4,) as a distinct zone of wear. No distinct cusp can be made out in front of the paracone although the cingulum is more pronounced there than elsewhere. Pm^3 is considerably longer than pm^4. There is no protocone although there is a thickening of the cingulum especially noticeable in the hinder half of the tooth. A cingulum is present externally also, as in pm^4. Also as in pm^4, the paracone is backwardly directed and there is a strong metacone, but no distinct parastyle. D. 146 (Pl. 29, fig. 3) is an isolated upper premolar, which from its size may be referred to pm^2 of the present species. It is smaller than pm^3 but, though in an advanced stage of wear, it exhibits precisely the characters which have been noticed in the case of that tooth.

[1] I here apply the same terms employed in the case of the molars to the analogous cusps in the premolars. This, however, does not imply that I hold any definite opinion regarding the homology or similar origin of these cusps.

The dimensions of these various teeth in millimetres are tabulated below with those of the maxilla, D. 148 and the mandible D. 142, to be described subsequently.

Dimensions.

	Dissopsalis carnifex.				Dissopsalis ruber.			Mandible of Dissopsalis.	
—	D. 143.	D. 144.	D. 145.	D. 146.	D. 147.	D. 148.	D. 174.	D. 142.	D. 149.
M^3 length . .					9·1				
M^3 breadth .					6·2				
M^2 length . .	26·1				21·3				
M^2 breadth .	22·1				17·8				
M^1 length . .	14·8								
M^1 breadth .	21·9								
Pm^4 length .	18·3 (?)	16·1	16·5			14·7			
Pm^4 breadth .	18·6 (?)	16·0	16·0			17·0	16·6		
Pm^3 length . .	17·6	17·8				14·9			
Pm^3 breadth	10·6	11·1				10·4			
Pm^2 length . .				15·0		11·8			
Pm^2 breadth .				8·5		6·9			
M_1 length . .								14·2	
M_1 breadth .								8·6	
M_1 height (paraconid)								8·5	
Pm_4 length . .								16·6	18·4
Pm_4 breadth .								9·8	10 8
Pm_4 height . .								14·6	

The Creodont characters of this dentition may be summed up as follows. Three upper molars are present, of which two are specialized as shearing teeth. This, united with the existence of

a tritubercular tooth in advance of these, is sufficient evidence that this species represents the primitive type of carnivorous dentition which belonged to the Creodonta.

The specialization of m^2 as the main carnassial, and the presence of m^3 leaves no doubt that it must be assigned to the family Hyaenodontidae.[1]

Comparison with other Creodont genera.

The dentition displays all the essential features of *Sinopa*, the Eocene genus which, though not so near the original type as *Proviverra*, yet retains all these primitive characters while showing alteration along the lines which succeeding genera were to follow more completely.

Thus *Dissopsalis* retains, like *Sinopa*, in the molars the primitive features of a distinctly separate paracone and metacone and a sharply pointed protocone situated at a considerable distance within the line of the outer cusps, though it exhibits a corresponding atrophy or partial atrophy of the parastyle accompanied by the development of the metastyle into a shear. Unlike *Sinopa*, however, *Dissopsalis* has carried the development of the metastyle to a degree which can only be compared with *Pterodon* and *Hyænodon*, which have hitherto been regarded as the latest of the group. In *Pterodon* and *Hyænodon*. however, this specialization of the metastyle has been accompanied by other changes which have not taken place in *Dissopsalis*. Thus *Hyænodon* has lost m^3 and the protocone of the molars. In *Pterodon* the protocone of the molars is considerably diminished and that of pm^4 has vanished, while in both these genera fusion between the paracone and metacone in the molars has occurred.

In *Dissopsalis* too, unlike *Sinopa*, the reduction or disappearance of the parastyle has extended to the premolars, where in pm^4 it is accompanied by an enlargement of the paracone, of which the cusp has become blunter.

Cynohyænodon has a well-developed metastyle, but paracone and metacone are closely connate. It differs also from *Dissopsalis* by the fact that m^1 is almost as long as m^2, instead of being only half that length. Further the short, compressed premolars distinguish it from *Dissopsalis*.

Tritemnodon has the connate paracone and metacone, without the long shearing blade of *Cynohyænodon*. It should be noticed

[1] The classification here adopted is the one formulated by Matthew in 1909, Matthew Carnivora and Insectivora of the Bridger basin, *Mem. Amer. Mus. Nat. Hist.* vol. IX, part 6, p. 327.

however, that *Dissopsalis* shows a decided tendency to this fusion of the paracone and metacone. These cusps are lower and closer together than is the case in any species of *Sinopa.*

Apterodon, like *Sinopa* and *Dissopsalis,* retains many of the primitive features. In this genus, however, the parastyle is almost equal to the metastyle, the development of the latter not being as far advanced as in *Sinopa.* On the other hand the inner cusps are lower and more rounded. This character, though not seen in the molars of *Dissopsalis,* is present in pm^4.

Quercytherium is distinguished by the extraordinary enlargement of the premolars, more especially of the anterior ones which are practically pyramidal teeth. The molars differ from those of *Dissopsalis* by the fusion of paracone and metacone and the lesser development of the metastyle.

Prorhyzœna like *Proviverra* is in an extremely early stage. The outer cusps are three in number and are of equal size, while the protocone occupies as much space as the entire three others. Attention may be called to the fact that m^3 of *Dissopsalis,* assuming that its outline is correctly indicated, differs from the corresponding tooth in all these other genera by its smaller transverse diameter. In the other members of the family the transverse exceeds the antero-posterior diameter, while the reverse seems to be the case in *Dissopsalis.*

Maxilla provisionally referred to *Dissopsalis ruber.*

The only maxillary fragments which remain to be noticed are D. 148 and D. 174. The former of these consists of three teeth which are so obviously of the same type as $pm^{2\text{-}4}$ of *Dissopsalis carnifex* as to leave us with little doubt that it belongs to a Creodont. Considering the fact that they are as much smaller than the premolars of the type maxilla of *D. carnifex* as the m^2 of *Dissopsalis ruber* is than the m^2 in the same maxilla, it seems at least possible that they may be the premolars of *Dissopsalis ruber.* In view of certain very significant differences of structure I am, however, quite ready to admit the equal possibility that they belong to a different species or even a different genus. Being unwilling, however, to establish a new generic or specific name on such slender grounds, I prefer for the present to class them provisionally with *Dissopsalis ruber.* I should like it clearly to be understood that this is done more as a matter of convenience than for any other reason.

Pm^4, of which the fragmentary D. 174 may be conjectured' to be a better preserved example, differs from pm^4 of *Dissopsalis carnifex* by the distinct presence of a parastyle. The protocone is smaller and more sharply pointed and there is no trace of the very prominent cusp which in *D. carnifex* serves to connect the protocone to the metacone. The transverse very considerably exceeds the antero-posterior diameter of this tooth. In pm^3, the thickening of the cingulum on the postero-internal margin of the tooth is so marked as to deserve to be called a cusp. Pm^2, beyond the difference in size, appears to differ in no respect from the corresponding tooth of *D. carnifex*, D. 146, figured in Pl. 29, fig. 3. The absence of a diastema between pm^2 and pm^3 may be noticed, in which respect it is like *Sinopa* rather than *Tritemnodon.*

Mandible.

It now remains to consider the question of the mandible. In the first notice of the species certain mandibular fragments were referred to as those of *Dissopsalis* under the mistaken impression that they had been found in association. At the time, indeed, I failed to understand how an animal, to which the maxilla of *Dissopsalis* belonged, could possibly have possessed such a mandible. Later the development of the teeth, formerly unexposed in this mandible, made the reference quite untenable, and the attribution to the genus *Hyaena* was proved and the question finally settled by the discovery of the precise spot in the Upper Chinji horizon, where these remains had been collected. In this spot fragments of a maxilla probably belonging to the same individual as the mandible were actually disclosed. Brief reference was made to these facts in my Correlation of the Siwaliks.[1]

In a subsequent field season the mandible D. 142, figured in Pl. 29, fig. 6, was collected from the Chinji beds. Although its attribution to *Dissopsalis carnifex* must be conjectural, yet the fact that it possesses just those characters which one would expect to find in the mandible of *Dissopsalis* seems to me to afford quite justifiable grounds for the provisional reference.

The fragment contains two teeth, the front one obviously a premolar and the hinder one a molar. Behind this again there was originally an alveolus, which has been lost in cleaning the specimen. The molar consists of a typical broad trigonid with a broad

[1] l. c. pp. 311, 312.

but low paraconid, a still lower metaconid and a large protoconid of which the cusp has been almost entirely lost by fracture. Behind is a basin-shaped talonid showing the traces of three cusps. This is as broad as the trigonid and only slightly inferior in length to it. The premolar is an altogether longer as well as stouter and taller tooth than the molar behind it. The summit of the main cusp is backwardly directed. The heel is well developed and exhibits an external trenchant blade, which slopes down internally into a broad shelf bounded by a slightly raised inner and posterior margin.

The primitive form of the trigonid of m_1 accompanied by the large pm_4 are features which are found only amongst the Creodonta. The structure of these two teeth may be compared with *Sinopa* in about the same degree that such a comparison obviously suggested itself in the case of the upper dentition described above.

Mandible compared with that of other Creodont genera.

The differences from *Sinopa* may in general be seen to take the same lines which they have followed in the case of the upper dentition, namely, enlarged premolars, general diminution in height and sharpness of the various cusps, slight reduction of the metaconid leading on to its total disappearance in *Pterodon* and *Apterodon*. The molars differ from those of *Tritemnodon* by the talonid being basin-shaped instead of trenchant. The mandible of *Cynohyænodon* is very like that of *Sinopa*, and the points in which the one genus differs from *Dissopsalis* apply also to the other. *Metasinopa* retains the metaconid as *Dissopsalis*, but unlike the Indian genus the talonid has been reduced and is trenchant as in *Tritemnodon*. *Apterodon* seems generally to possess the broad, primitive talonid of *Dissopsalis* but the metaconid is vestigial. *Pterodon* and *Hyænodon* resemble *Dissopsalis* in regard to the enlargement of pm_4 and the corresponding shortening of m_1, but the absence of the metaconid and the trenchant talonid clearly separate them from our genus. *Quercytherium* has a shorter talonid than *Dissopsalis* and the metastyle of pm_4 seems also to be less developed. In other respects it shows certain similar features to the Indian genus, but owing to the fragmentary condition of our specimen no comparison is possible in what is the most essential peculiarity of *Quercytherium*, namely, the enlargement of the anterior premolars. *Galethylax* is a small primitive, little known form, which resembles *Quercytherium* on account of its enlarged pm_2. It seems

in other respects to be near *Cynohyœnodon*. The size of m_1 as compared with that of pm_4 much exceeds what is the case in *Dissopsalis*.

The generic characters of *Dissopsalis* may be summed up as follows :—

Dentition I ? C. P.$\frac{4}{4}$ M.$\frac{3}{3}$

Upper molars ; m^2, m^3 paracone and metacone separate but closer together than in *Sinopa*, protocone prominent, parastyle reduced, metastyle prolonged into a shear, which is more pronounced in m^2 ; m^3 longer than broad.

Upper premolars ; pm^4 tritubercular, enlarged, parastyle absent or reduced (?) protocone very strong, with stout, blunt cusp ; pm^3 longer than pm^4, protocone reduced to a thickening of the cingulum.

Lower first molar ; trigonid with strong protoconid, lower paraconid, and still lower metaconid, talonid long, basin shaped, with traces of 3 cusps.

Lower pm_4 *;* enlarged, with a well developed heel consisting of an external trenchant portion and an inner shelf.

Origin of *Dissopsalis*.

From the affinities of these remains, which have been discussed above, it is possible to form some conclusions as to the probable history of the genus.

We need go no further back than *Sinopa* to find an ancestral type from which *Dissopsalis* may have descended. Beginning in the Lower Eocene, *Sinopa* persists in America until the Middle Eocene. Smaller species have been recorded from Switzerland.

Dissopsalis would seem to have developed from *Sinopa* along a line parallel to that of which successive stages of divergence are found in *Tritemnodon* of the Lower and Middle Eocene of America, in *Cynohyœnodon* of the Upper Eocene of Switzerland, in *Apterodon* and *Pterodon* of the Lower Oligocene of Europe, Africa, India and North America (the latter of these it may be noted is found as the gigantic species *Pterodon bugtiensis* in the Upper Aquitanian beds of the Bugti Hills of Baluchistan) culminating finally as far as our present information goes in *Hyœnodon* of the Middle and Upper Oligocene of Europe and America.

Diagrammatic representation of descent of *Dissopsalis*.

The accompanying diagram, which is adapted with modifications from Matthew will explain the suggested line of development. As Matthew has stated, " the main line from *Sinopa* to *Hyœnodon* may be regarded as passing through hypothetical marginal species of each genus, not through any of the typical or

known species " D1 to D5 may be taken to represent successive hypothetical stages leading gradually to *Dissopsalis*.

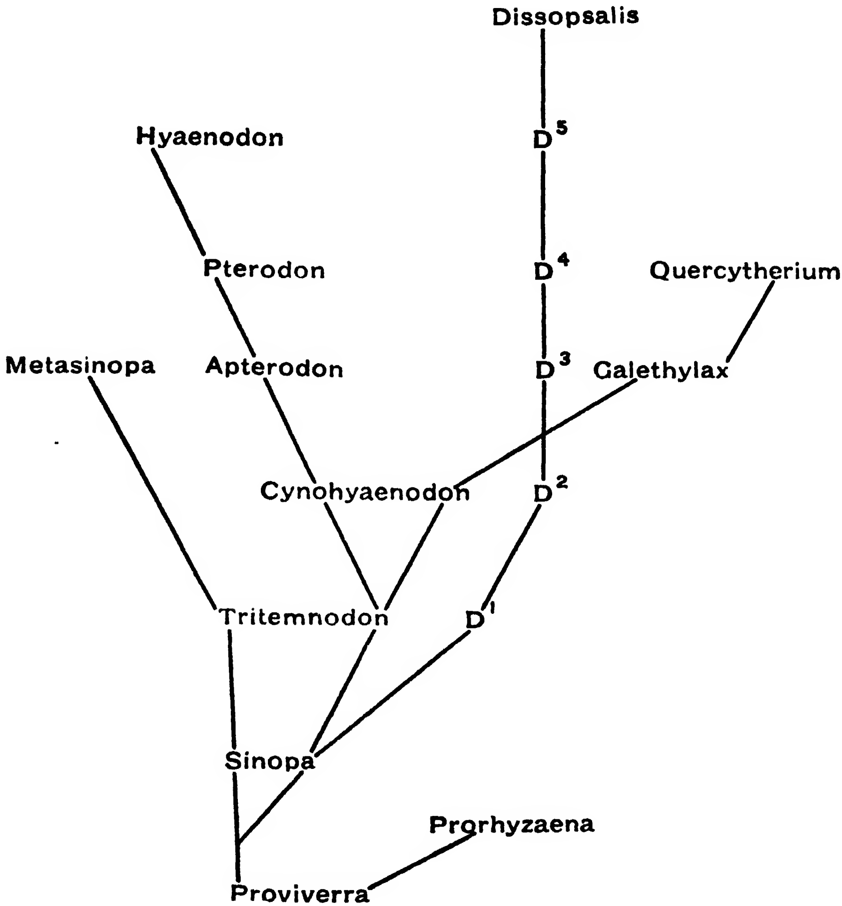

Fig. 15.—Diagram to illustrate the evolution of the Hyænodontidæ adapted after W. D. Matthew.

The hypothetical ancestor D1 of *Dissopsalis* tended somewhat in the same direction as *Tritemnodon* in the approach to fusion of the paracone and metacone and in the reduction of the metaconid. No actual compression has taken place in the premolars although the protocone of pm^3 is well on the way towards the atrophy

which has completely resulted in *Tritemnodon*. The protocone of the upper molars, however, remained as in *Sinopa* and no reduction has occurred in the heel of the lower molars.

The development of the type of upper molar, in which the metastyle has become elongated into a shearing blade, can be seen in the supposed passage of D1 into D2 just as in that of *Tritemnodon* into *Cynohyœnodon*, except that this carnassial specialisation tends in *Dissopsalis* to be concentrated on m^2 rather than on m^1. From this point the elongation of the metastyle must have continued in the *Dissopsalis* line in a corresponding fashion to the parallel line which starts from *Cynohyœnodon*, in which progressive stages of development of this feature may be seen in *Apterodon*, *Pterodon* and *Hyaenodon*. Indications of affinity to *Apterodon* may be found in the stoutening and rounding off of the protocone of pm^4. In *Apterodon* this has occurred throughout the dentition. The enlargement and increase in shearing power of the metaconal cusp of m^2 seems to be paralleled in the *Dissopsalis* line, as also is the progressive insignificance of m^1, seen especially in *Hyœnodon*. This is accompanied in *Hyœnodon*, as in *Dissopsalis*, by enlargement of the premolars. This last character has been carried to excess in the parallel line of *Quercytherium*.

Dissopsalis, however, shows no tendency to imitate these other genera in the progressive atrophy of the protocone in the molars, a character which they would seem to bring with them from their *Tritemnodon* ancestor, or of the metaconid and heel of m_1.

Beyond the stage assumed to correspond to *Hyœnodon*, it would appear that little modification has taken place in *Dissopsalis*, so far as our material affords us grounds for judging. Though it must not necessarily be assumed that this stage was reached as early as the Upper Oligocene when *Hyœnodon* flourished, still it is probable that *Dissopsalis* presents us with an example of an animal, which for some considerable time had altered little, and lingered on past the period when the vital powers of the race were capable of effecting further modification, possibly because it possessed certain bodily characters of which we know nothing, better adapted than those of other Creodonts to an altered environment, but in any case an archaic type quite out of place amongst the modernised surroundings of the Lower Siwalik period.

EXPLANATION OF PLATE.

PLATE 29.

FIG. 1.—*Dissopsalis carnifex,* Pilg. right maxilla with m^2 to pm^3, surface view, type of the species (Ind. Mus. D. 143).

FIG. 2.—*Dissopsalis carnifex,* Pilg. fragment of left maxilla with pm^3 and pm^4, surface view (Ind. Mus. D. 144).

2a.—The same, external view of pm^3.

FIG. 3.—*Dissopsalis carnifex,* Pilg. right pm^3, surface view, (Ind. Mus. D. 146).

FIG. 4.—*Dissopsalis carnifex* Pilg. right pm^4, surface view (Ind. Mus. D. 145).

4a.—The same, external view.

FIG. 5.—*Dissopsalis ruber,* Pilg. left maxilla with m^2 and m^3, surface view, type of the species (Ind. Mus. D. 147).

5a.—The same, external view.

FIG. 6.—(?) *Dissopsalis carnifex,* Pilg. left mandible with m^1 and pm^4 (Ind. Mus. D. 142).

6a.—The same, external view.

6b.—The same, internal view.

FIG. 7.—(?) *Dissopsalis ruber Pilg,* left maxilla with pm^2 to pm^4, surface view (Ind. Mus. D. 148).

7a.—The same, external view.

All figures natural size.

NOTES ON SOME GLACIERS OF THE DHAULI AND LISSAR VALLEYS, KUMAON HIMALAYA, SEPTEMBER 1912. BY CAPTAIN JOHN L. GRINLINTON, R.G.A., F.R.G.S. (With Plates 30 to 43 and text figures 16 to 28.)

SUMMARY OF CONTENTS.

THE following paper embodies both observed facts and certain deductions made therefrom. In those cases in which remarks of a conjectural nature have been made, they are put forward with extreme reserve. They represent the most reasonable interpretation of certain features, as they appeared at the time of observation in the field; but being of the nature of an individual opinion they should not be confused with the facts noted. An endeavour has been made to confine my remarks, as far as possible, to a record of observations. As the work has progressed, however, it has been found very hard to avoid some sort of conjecture as to the meaning of certain forms, to serve as a means of connecting, if nothing else, what would otherwise be a mere series of disjointed notes.

It is to be remembered that many observations recorded herein are common facts, well-known in Alpine and other glaciers. They are, however, placed on record, as observations on Himalayan glaciers are not numerous, considering that thousands of such ice-streams exist in these mountains; hence even ordinary points of similarity with other glaciers seem worthy of note.

AREA IN WHICH OBSERVATIONS WERE MADE.

This is shown on the Atlas of India ¼-inch=1 mile sheet 66 N.-E., a part of which is reproduced in Pl. 40. The glaciers examined were the following :—

Baling (very slight examination).
Sona.
Cholungli (debouchure only).
Naulphu (snout fixed only).
Nipchungkang.
Dangan and Yamerson (some ancient terminals only).
Kharsa.
Chingchingmauri.
Ralphu (some ancient terminals only).

The whole of the Lissar and Dhauli valleys are very interesting from a glacial point of view. It is true that none of the glaciers in this area are at all large, even as compared with those of the Nanda Devi group, some 25 miles to the west, but the following points make them very well worthy of study :—

(*a*) They show a remarkable similarity to one another, flowing in parallel troughs formed under very similar conditions of denudation.

(*b*) The stages of over-deepening of the Lissar and (subsequently of the Dhauli), on the other hand, show a regular advance towards maturity from the source downwards.

(*c*) This enables the observer to link up cause and effect by visiting the debouchure of each glacier in succession, and by viewing a very similar process of denudation in each case at different stages in its progress.

The visit was made during September 1912. Glacial observations commenced at Baling on 5th September and that glacier was repassed on the downward march on 19th September. It would have been possible during this interval of two weeks to have pushed right up to the head of the Lissar valley. The relations of the snouts of the glaciers mentioned on page 282 to the valley bottom of the Lissar nadi were found, however, to be so interesting, that it seemed better to devote all the time possible to a detailed examination of these, rather than to making a very sketchy series of observations on the glaciers of the whole valley.

During September 1912 the Lissar valley was found to be quite accessible and observation was easy. It may be reached from Almora by the following easy stages :—Almora, Dolchina, Ganaie, Thal, Askot, Balwa Kot, Darchula, Khela Syalapanth, Sobala (Nyu), Sela Gat, Baling (10 marches, of which none are over 17 miles). Chuprasis from Almora Kucherry are required as far as Askot. At Askot the Rajwar Sahib will arrange further marches if he receive previous notice by letter. Native supplies are plentiful in September.

It was determined to confine all work to a limit below the 14,000 feet contour, as much time would otherwise have been spent in climbing. For this reason these notes are of the nature of a short preliminary reconnaissance only.

The headings under which they may be grouped are as follows :—

I.—Positions of the snouts in 1912.
II.—Valleys, main and tributary.
III.—Lakelets and ponds. Points with reference to drainage.
IV.—Former glaciation.
V.—Ice, and other features of the glaciers themselves.

It will of course be understood that II and III have been regarded from a glacial point of view alone.

I. POSITION OF SNOUTS IN 1912.

Baling and Sona Glaciers.

Baling Glacier.—The snout of this glacier can be reached by a short scramble from the main path up the Dhauli river near Baling village. The ice cave is visible from the path. The Baling glacier is marked on Atlas of India quarter sheet 66 N.-E. as 30° 10′ 40″ N. 80° 37′ 0″ E.

Sona Glacier.—Sona is half a march from Baling, the usual camp being just past Sona at Dhaktu. The ice cave may be reached in less than one hour's very easy walking up the Sona valley by one of the many grazing tracks. There is ample firewood near the snout and in September native supplies are plentiful.

The Sona glacier is marked on Atlas of India quarter sheet 66 N.-E. as 30° 15′ N. 80° 37′ E. It is very much larger than one would suppose from this map. As is noted on the map (Pl. 43) the values in length for this fix are very rough with the exception of the distance from station V to the white stone at the mouth of the ice cave, which is accurate. The real "fix" depends on the photographs and bearings recorded in table A below.

Baling and Sona Glaciers.

TABLE A.

Position of snouts in September 1912.

Baling Glacier.—Height of ice cave above M. S. L. at point of issue of stream from cave.	10,660 feet fixed on 5th September 1912.	
Sona Glacier.—Map on which details are shown .	Pl. 43	
Height of ice cave above M. S. L. at point of issue of stream from cave.	11,090 feet.	
Stations marked in the field.—A small cairn round which 3 fires were lighted to mark the grass. A rock 42 feet away from the cairn on a magnetic bearing of 191¼ degrees was marked with 3 straight cuts, each cut about 1 foot long and 1 inch broad.	Sona station III fixed 17th September 1912.	See Pl. 43.
No mark was left in the field, but bearings were taken to the Panch-chula peaks as follows :— 21,114 ft. 213½ deg. M. B. 20,780 ft. 223¾ „ „ 20,700 ft. 232¼ „ „ 22,660 ft. 243¾ „ „	Sona point *a* fixed 17th September 1912.	See Pl. 31, fig. 1. Bearing of centre line of camera 223 degs. magnetic.
The letter A cut on a rock "waist high" on the north side of the grazing track passing station IV. The rock touches the track.	Sona station IV fixed 17th September 1912.	
A "broad arrow" was cut in a huge rock on the right lateral, and the camera was set up over a stone 5 feet from the "broad arrow" on a magnetic bearing of W. by S. A small cross was cut on the rock over which the camera stood.	Sona station V fixed 17th September 1912.	Pl. 30, fig. 1. Panorama bearing of centre line of camera 291¾ degs. and 267¼ degs. magnetic.

Naulphu Glacier—Route to.

The ice cave of the Naulphu glacier is reached from Sipu village by a grazing track along the left (N.) side of the Mula gar valley. The Naulphu glacier is also known locally as the Mula-garka-gal, Mula gar being the local name for the glacier stream coming from the Naulphu glacier. The climb to the snout from Sipu takes some 2 hours 50 minutes and the return journey about 2 hours. In rainy weather it is an exceedingly dangerous place as the stone chutes down the left (N.) side of the valley are very active. The local Bhotias dislike going up except in clear weather.

The Naulphu glacier is marked on Indian Atlas quarter sheet 66 N.-E. as 30° 17′ N. 80° 30′ E. Sipu is one march from Sona, being the last village up the Lissar nadi. In September local supplies are moderately plentiful.

The "fix" of this snout as shown in table B, below, is accurate though the details are somewhat few; and it is possible that it would take some little trouble to find station A. No more, however, could be done as violent wind, rain and mist prevented further work. It will be seen from Pl. 30, fig. 2 that the ice cave was photographed during a break in the mist; the upper portion of the picture shows the mist rolling away.

Naulphu Glacier.

TABLE B.

Position of snout in September 1912.

Diagram on which details are shown . . .	Pl. 39, fig. 1.	
Height of ice cave above M. S. L. at point of issue of stream from cave.	13,110 feet.	
Stations marked in the field.—The letter A cut on the vertical face of rock just above a peculiar level ledge on N. side of valley. The position of the camera at station *a* was 6 feet from A on a magnetic bearing 233½ degs.	Naulphu station *a* fixed 8th September 1912.	Pl 30, fig. 2. Bearing of centre line of camera 180¾ degs. magnetic.
Was marked with a small X cut on the horizontal surface of a shoulder of rock 148 feet from A on a magnetic bearing of 233½ degs.	Naulphu station *β* fixed 8th September 1912.	See Pl. 39, fig. 1.

Nipchungkang Glacier—Route to.

The snout of this glacier is reached by an easy half march from Sipu village. As Sipu is the last village up the Lissar nadi supplies have to be taken for coolies. The snow pass to Ralam in Johar is reached *viâ* the Nipchungkang valley. The pass lies somewhat to the south of the point marked on the Atlas sheet. The snout can just be seen from the point where the Nipchungkang glacier stream enters the Lissar nadi. The position of the Ralam pass cannot be seen from this point. It can, however, be seen from Nipchungkang station VIII. (See Pl. 41.) Water and wood are plentiful near the snout.

The Nipchungkang glacier is marked on the Atlas of India quarter sheet 66 N. E. as 30° 18′ N. 80° 33′ E.

The triangulation round the snout of this glacier was done with plane table. The base was measured with a steel tape between stations II and III. Note that station III was marked with the letter Y cut on the face of a red boulder on the left lateral. This has not been recorded in table C below.

Nipchungkang Glacier.

TABLE C.

Position of snout in September 1912.

Map on which details are shown	Pl. 41.	
Height of ice cave above M. S. L. at point of issue of stream from cave.	12,670 feet.	
Stations marked in the field.—The letter A, about one foot high, cut on a rock. This letter can be seen with ease from station II with a pair of field glasses, power 6. The clino. from station II to station IX is +2¾ degs.	Nipchungkang station IX fixed on 11th September 1912.	See Pl. 32, fig. 1. Magnetic bearing of centre line of camera was 309¼ degs.
The letter X cut on a rock situated on a small birch covered spur. A cairn about 3 to 4 feet high was also put up over this station. This cairn can be seen from station II with a pair of field glasses, power 6, though somewhat hard to find as the back ground is bad. The clino. from station II to station X is −20 degs.	Nipchungkang station X fixed on 10th September 1912.	See Pl. 31, fig. 2. Magnetic bearing of centre line of camera was 269¼ degs.
A small cairn was built on the left lateral to mark station II, but as this station is exposed to bombardment from a stone chute an extra mark was cut on the flat upper surface of a slab of rock close to the grazing track passing this station. This rock is 44 feet from the cairn on a magnetic bearing of 299¼ degrees.	Nipchungkang station II fixed on 10th September 1912.	See Pl. 32, fig. 2. Magnetic bearing of centre line of camera 225 degs.

Kharsa Glacier—Route to.

The snout of this glacier is reached by one march from Sipu. It is near a well-known grazing ground, while in the neighbourhood of the snout a few Bhotia shelters are situated. Supplies for coolies must be taken. The Kharsa glacier is marked on the Atlas of India quarter sheet 66 N.-E. as 30° 22′ N. 80° 20′ E.

The sketch map of the snout of the Kharsa glacier (Pl. 42) was done with plane table and is accurate. The absolute values of length should be fairly good as they are obtained from a sub-base put down with steel tape and theodolite. But in making an estimate of any future advance or retreat it would be as well to re-check some one side of one of the triangles with tape or chain as the work was done single-handed, with the exception of the assistance of a Bhotia coolie.

Kharsa Glacier.

TABLE D.

Position of snout in September 1912.

Map on which details are shown	Pl. 42.	
Height of ice cave above M. S. L. at point of issue of stream from cave.	12,510 [H]. 12,645 [C]. H. Ig. hypsometer direct. C. Ig. clinometer and hypsometric ht. of station I.	
Stations marked in the field.—Situated on a portion of an ancient terminal. A small cairn built to mark the spot and the letter Y was cut on the rock on which cairn was built. The position of station Y may be recognised from the photograph Pl. 33, fig. 2. From Kharsa station β to station Y the magnetic bearing is 319 degrees and clino. is $+3\frac{3}{4}$ degs.	Kharsa station Y fixed 13th September 1912.	See Pl. 33, fig. 1. Magnetic bearing of centre line of camera $208\frac{1}{2}$ degs.
Marked with a small cairn. As this station is near the edge of a somewhat unstable cliff it may get destroyed by denudation in a few years, so Kharsa station III was also marked by cutting the letter A on the rock composing it.	Kharsa station β fixed 15th September 1912.	See Pl. 33, fig. 2. Magnetic bearing of centre line of camera 319 degs. (See also field sketch Pl. 37.)

Chingchingmauri Glacier—Route to.

The snout of this glacier can be reached by an easy walk of about one hour from the snout of the Kharsa glacier, up the Lissar valley. In front of the snout lies a well-known grazing ground. A few very rude shelters are scattered here and there. The Chingchingmauri glacier is marked on the Atlas of India quarter sheet 66 N.-E. as 30° 23′ N. 80° 30′ E.

Chingchingmauri Glacier.

TABLE E.

Position of snout in September 1912.

Map on which details are shown	Pl. 42.	
Height of ice cave above M. S. L. at point of issue of stream from cave.	13,690 feet.	
Stations marked in the field.—The actual station itself was not marked, but on a rock near it the mark N was cut. The distance from the plane table to the marked rock was 20 feet and the magnetic bearing was 286¼ degrees from plane table to rock.	Chingchingmauri station XXIII.	
Marked by a slab of rock, the N.-E. face of which was marked with the letter Z. A small cairn was built on the rock. From station XXI to station XXII the M. B. was 293¾ and clino. +10½ degrees.	Chingchingmauri station XXI.	
A large boulder near the lakelet marked ϕ on the west face of the rock.	Chingchingmauri station XXV.	

VALLEYS, MAIN AND TRIBUTARY.

The Lissar and Dhauli Valleys.

As the Lissar nadi is a tributary of the Dhauli river, it is important to note the progressive variation in cross-section of both these valleys, in order to compare the types within and without the zone of glaciers.

Every stage has been observed illustrating a gradual transition from A, an open "U"-shaped high level valley, with over-deepening at an early stage, through B, an intermediate stage. with over-deepening very pronounced, to C, a "V"-shaped valley, at a considerably lower level than type A.

It should be noted that, in considering the above changes of type in cross-section, the change of the nature of the rock forming the valley side must be allowed for: type A is all within the zone beyond the crystalline rocks, class B lies (in part at least) on the northern limit of, and type C within the crystalline zone.

Gorges.

At Sobala on the Dhauli river in lat. 30° 4′ N. there is a fine gorge, such as one might expect to find at the sudden bend of a Himalayan river. In several instances the slope from

the path to the river is 52 degrees as measured with the clinometer: and this for a height of quite 500 to 800 feet above the water level.

The sides of the valley above this point are very steep, but the next true gorge cannot be said to occur until between Sela and Baling. Above this point no true gorge occurs on the Lissar, though the over-deepening is so great in places that it almost amounts to one: for example, the considerable constriction of the Lissar valley between the Sipu flats and the Kharsa grazing ground, and again between the Kharsa grazing ground and the Chingchingmauri grazing ground. Both these constrictions approximate to gorges, though they are not very well-marked ones.

Gorges of the Dhauli and Lissar rivers.

The Dhauli exhibits a sharp bend just north of Dakar which runs through a distinct gorge. Pl. 35, fig. 1 shows this. It is impossible to appreciate fully the steepness of the sides near the bottom of the valley as the overlapping of the ends of the fan masks the effect. But some idea may be gained of it by noting how high the track to Tibet is carried along the valley side.

In none of the glaciers examined were any cases of true "Roflas" seen. But many of the glacier streams have cut down very deep into the old valley bottom near their entrances to the main stream to which they are tributary. The stream from the Gunna glacier (near Sela) enters the Dhauli through such a cut. The Sona glacier stream and that of the Kharsa glacier also exhibit this feature.

The types may be represented diagrammatically in figs. 16, 17 and 18.

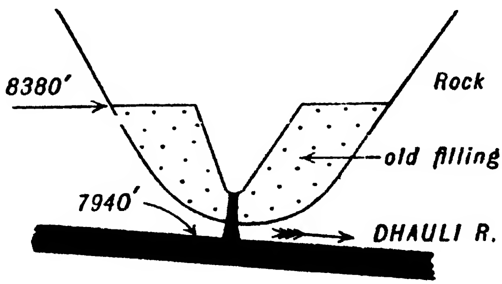

FIG. 16.

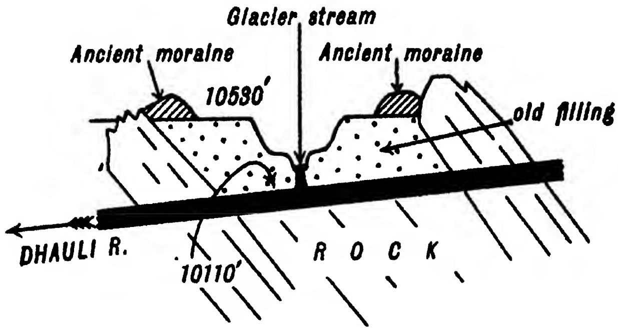

FIG. 17.

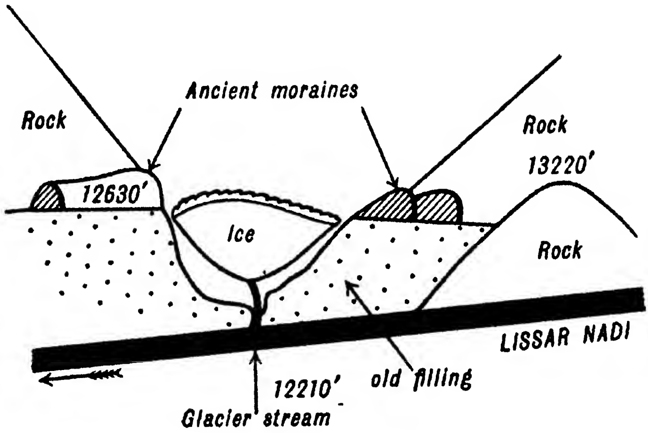

FIG. 18.

Elbows in River Courses.

Near Sobala the Dhauli takes a very sudden bend and passes through the ridge of the Panchchula range. The course at the bend is at right angles to the strike of the rocks, which latter dip at a very high angle to the N.-E.

Again, in latitude 30° 17′ N. near Dakar a similar bend occurs, in this case associated with the entry of the Lissar nadi as a tributary.

The bend at Sobala marks the southern boundary of the zone of glaciers in this area. That near Dakar marks a distinct change in type of the glaciers draining into the Lissar-Dhauli waters. It is worthy of note that the following three points lie exactly in a straight line :—

Southern limit of glaciers near bend at Sobala.

(1) Junction of Shunkalpa glacier stream with Gori river (Johar).
(2) Junction of Lissar and Dhauli rivers (Darma).
(3) Junction of Kali with a tributary near Sang chuma (Darma).

This line is practically at right angles to the flow of the rivers in this area, all of which latter run parallel one to another. It may also be noted that the Panchchula massif and the Lebung pass both lie close to this line.

Over-deepening of Valleys.

To appreciate fully the relationship between present and past glaciation it is necessary to recognise the effects of over-deepening well outside the present zone of glaciers as well as within it.

But it must be understood that when over-deepening is mentioned in these notes it is intended that the term should refer to the latest phases of this action. As is well known, almost all Himalayan valleys exhibit examples of profound over-deepening along the belt connecting the Sub-Himalayan ranges and the main axis (or axes) of elevation. Almost every writer on Himalayan orography has noted this point from the late Sir Joseph Hooker downwards.

Over-deepening at two great epochs.

Fine examples of this profound over-deepening may be noted about Mansari in Johar (Kumaon), and also near the junction of the Kali and Gori rivers in the vicinity of Askot (Kumaon (lat. 29° 45′ N. Atlas of India ¼ sheet 66 S.-E.)

But this profound over-deepening has been so great that it has apparently removed all, or almost all, traces of glaciation previous to it. For the purposes of these notes "over-deepening" may be taken to refer to that which has taken place so recently that the shelf resulting

The over-deepening at the latter of these two epochs connected with still visible remains of former glaciation.

from it is still visible, there being remnants of the ancient valley bottom still remaining *in situ* within some 300 to 500 feet of the present water-level.

At the junction of the Gori and Kali rivers near Askot there are some interesting terraces. Villages are built on the uppermost ones. The degree of over-deepening may be estimated from the following diagram (fig. 19). The Gori meets the Kali at an even gradient, though to the eye it would seem to be the swifter of the two confluents.

Over-deepening near junction of Kali and Gori rivers.

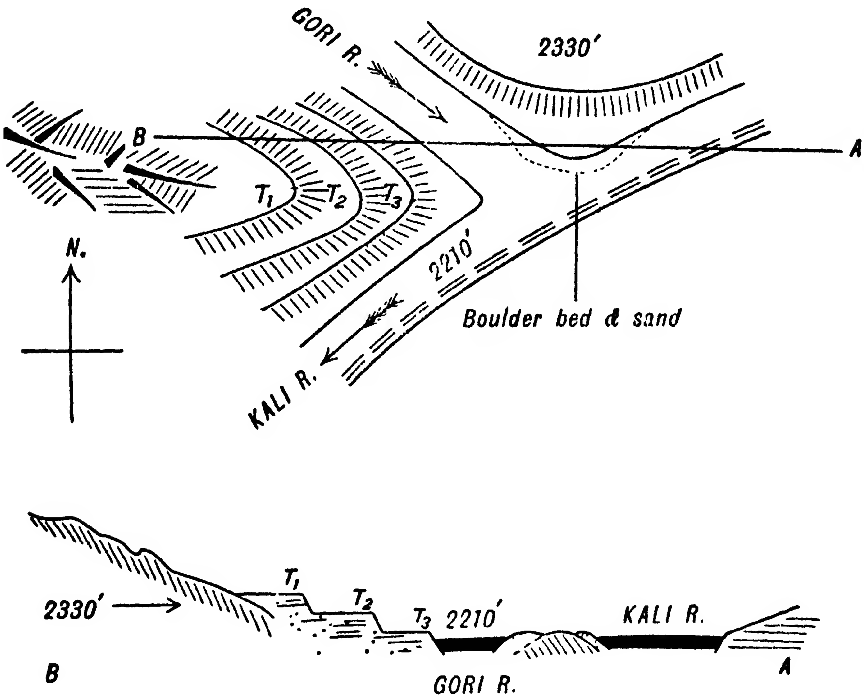

FIG. 19.

The height of the Kali at this point above sea-level is 2,210 feet; that of terrace T_1, about 2,330 feet.

The series of three well-marked terraces above the present water-level is the most noteworthy feature.

Near Darchula.

Between Askot and Khela Syalapanth the Kali shows several terraces, all giving evidence of this threefold over-deepening. At Darchula the greater number of the houses are built on the uppermost of the series of terraces, at a height of some 265 feet above the present water-level.

Near Khela Syalapanth.

In the neighbourhood of Khela Syalapanth where the Kali runs in a gorge, unmistakable evidences of recent over-deepening are to be found just south of that village.

On the Dhauli river excellent examples of terracing are frequent. At and above Baling the evidences of over-deepening are most marked, exhibiting very fine examples of this feature in all its stages.

Valley filling between Baling and Sona.

The valley bottom between Baling and Sona is filled with practically horizontal beds of gravel and rounded boulders. There are some sandy beds. Through this the Dhauli has eroded a deep channel: near Baling the prevalent dip of the strata forming the true sides of the valley is N.-E. and so the river clings to the left side of the valley under-cutting the steep cliffs. For this reason not much of the horizontally bedded filling is left there. But on the S.-W. (right) side of the valley there is still a considerable remnant. Some few of the more sandy upper beds near here show current bedding. On the right bank near Baling fans of detritus have been superimposed on the horizontal beds. There are, however, indications in several places that the Dhauli had cut down some way into the "filling" before the fans formed on top of it to any great extent.

Higher up the valley near Sona the filling is very well shown and the beds are clearly seen. Detrital fans here also spread on top of it. But the valley is open, and so the toes of the fans trail off to a very easy slope before they are truncated by the river. The general average size of the larger boulders, etc., near Sona is greater than that of those near Baling. There is more sand in the filling near the latter place. The approximate general slope from Baling along the top of the "shelf" towards Sona

is from ½ to 1 degree. The amount of over-deepening at Sona is 420 feet as measured with the hypsometer; at Baling it is considerably more.

Above Sona up to Dakar the over-deepening and terracing is again very well exhibited.

Near Kharsa.

In the Lissar nadi at Sipu the amount is 300 feet and at the Kharsa grazing ground it is 420 feet, the former measured by hypsometer and the latter with steel tape and clinometer. Pl. 36 shows the over-deepening in this section.

Near Chingchingmauri.

In the Chingchingmauri area over-deepening is less marked than near Kharsa, and evidently has not proceeded beyond the early stages.

Longitudinal Section of Rivers.

The position of the "shelf" has been established pretty well by observations, and by extracts from barometric values given on the Atlas sheet.

The marked change of grade of the Dhauli river just before entering the crystalline zone near Sona is interesting, and confirms former observations on this point.

The constriction between Sipu and Kharsa mentioned above, p. 289, is seen in the section to be marked by an extra steepness in grade of the Lissar nadi.

All the glaciers to right and left of the route followed are not shown, only those whose height was actually measured at the ice cave. A table of hypsometrical heights is added at the end of this paper; also a short discussion of the degree of accuracy of the observations (*infra*, p. 333).

Meanders and Side-cutting.

A few terraces round Sipu and in the Kharsa area show very curved traces in plan. But these seem to be due to deflection sweeps caused by fanning at a former stage of denudation. They are not curved enough for, nor of the character of, meander

curves. At the present time the stream is of course swift and direct in this area.

Side-cutting is seen locally, but it is not of a very pronounced character.

Hanging Valleys and Cascades.

On the Dhauli river between Khela Syalapanth and Sobala there are many small hanging valleys and numerous cascades delivering into the river from both banks. There are also several well-marked instances of hanging valleys and cascades between Sobala and Nangling.

Relation of present hanging valleys to ancient valley bottom.

Above this point on the Dhauli, right up to the Lissar Dhauli junction at Dakar, all the glacier valleys which enter the Dhauli valley are hanging to a greater or less degree. Most of them appear to have delivered at grade, or very nearly at grade, into the ancient valley bottom now represented by the shelf on which all the villages in the valley are built. But they are of course high up above the present valley bottom.

There is, however, a distinct tendency for minor tributary valleys in this section to hang above even the remnants of the ancient valley bottom. An instance may be quoted in the case of the small valley between Baling and Sona on the right bank of the Dhauli (Pl. 31, fig. 2, and Pl. 32, fig. 1).

Sona valley not a hanging one.

The Sona valley is somewhat different to others in this area. The gathering area is large and it evidently met the ancient Dhauli valley at grade. Indeed there is a certain amount of evidence tending to indicate that the Sona valley once was somewhat lower than it is now and delivered into the Dhauli valley at grade before the floor of the latter had been aggraded by the present filling. The process of aggrading took place equally in both valleys for some time subsequently so that they eventually met at grade at a higher level than formerly. Then a period of rejuvenation of the streams may be presumed to have taken place, and both cut down into the filling already deposited, the Sona stream managing to keep place with the Dhauli at the mouth of the former stream.

The three abovementioned stages are shown roughly in the diagrams in fig. 20 (see also fig. 17 above).

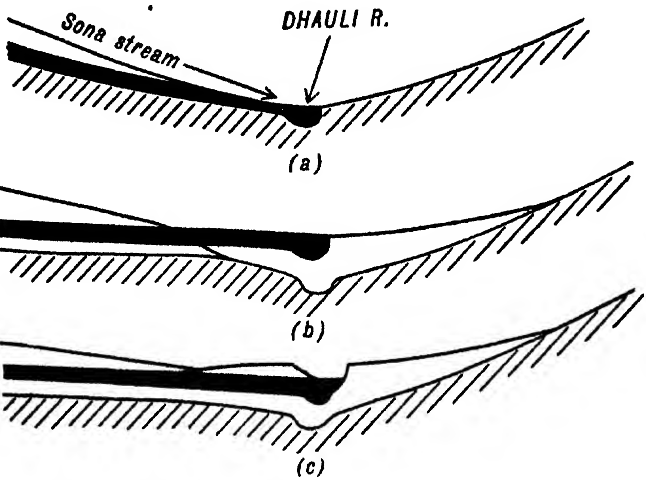

FIG. 20

These points are of importance from a glacial point of view, because, as will be seen later, in addition to the above action, glacial deposition has further added to the complication of the above features.

Above the Cholungli glacier up to the Chingchingmauri, the Naulphu, Nipchungkang and Kharsa may be said to deliver at grade into the Lissar while the Dangan, Yamerson and Chingching-mauri may be correctly described as "hanging," the Chingchingmauri to a lesser degree than the other two.

The rocky entrance to the Dangan valley is shown in Pl. 35, fig. 2, just under the sharp pyramid peak on the right. The truncation of the fan and moraines from this valley at the edge of the "shelf" and the commencement of the drop to the Lissar nadi are also clearly to be seen near the centre of the picture.

Fans.

The fanning from Baling up to the Chingchingmauri is everywhere a marked and important feature. It is a point which requires much careful study from a glacial point of view as the

relationship between fans and moraines are as a rule fairly easy to recognise. This enables a rough estimate to be made of the sequence of events, giving the observer some idea as to the pulsations of glacial activity which have taken place, though of course no idea of the actual time values.

Fan at mouth of Cholungli glacier valley.

Pl. 34 is of peculiar interest. It shows the debouchure of the Cholungli glacier valley into the Lissar valley between Dakar and Tizang. The foundation on which the ancient moraines of the Cholungli glacier seem to rest is really the massive detrital fan formed at the valley mouth previous to the deposition of the visible moraines. The stream in the centre is cutting down into the fan at the present day. The details of the moraines, subsequent denudation, etc., will be noted further on when considering "former glaciation."

It seems probable that the fan has been increased on the northern (Tizang) side since the moraines were deposited, the material having been carried down through the opening between the moraines seen in the plate. The fan is not quite so highly developed on the southern (Dakar) side.

Fan formation may be seen between Sona and Dakar on the right bank of the Dhauli. The village of Dakar really rests, in part on the foundation fan on which the ancient moraines of the Cholungli glacier are deposited. A terrace formed here is really composed of fan ends which have been partly cut away by the Dhauli river.

Pl. 35, fig. 2 shows the fans on the right side (west) of the Lissar valley just below the entrances of the Dangan and Yamerson valleys. In the right centre of the picture is seen the fan at the mouth of one of these two small glacial hanging valleys, exposed in section by the deep cut of the side stream. It is interesting to compare this with the type of the fans of pure denudation. The former has evidently been modified by the action of superincumbent ice at one period of its life-history. It shows the "shoulder" peculiar to such action. The change in gradient at this "shoulder" can be well-seen if the top line of the natural section be followed up to a point practically in the same vertical plane as the sharp needle peak in the right upper quarter of the plate. Many other examples may be seen of local fanning in this area. they are all worthy of examination in the field by future

observers, as it is astonishing how frequently peculiar points in the disposition of fans assist the eye in picking up important glacial features which have been partially smothered by the detritus due to subsequent denudation.

In some instances cross-sections of fans have been exposed by small tributary streams, which seem to indicate that a certain amount of cutting down into the old valley bottom had been done by the Lissar or Dhauli before the fans started accumulating in any great measure.

Occasionally a fan may mask the original "shoulder" produced in the early stages of over-deepening. This is shown diagrammatically in fig. 21 in which F_1 F_2 F_3 F_4 represent the fans in section. It will be noted in (*c*) that the end of the fans overlap the first "shoulder" of the over-deepening.

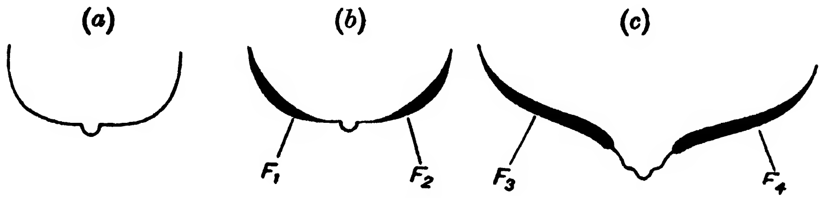

FIG. 21.

Near Kharsa station VIII (see Pl. 42) there is a somewhat important section exposed by a small but deep tributary nullah. This is shown in fig. 22.

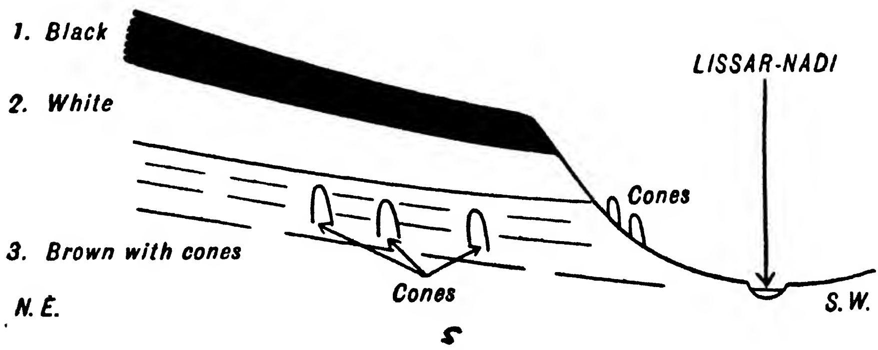

FIG. 22.

This section is important because it is one of the few which convey in the field an impression to the mind, amounting almost to a certainty, that the member "3 Brown with cones" runs under the present fans and the "cones" are remnants of it.

This is a matter of very great importance from a glacial point of view.

If it were not for the evidences of this section (and one or two more like it) it might be possible to place a different interpretation on the features exposed. That is to say, the members 1 Black and 2 White might be taken as masking the ancient shelf as now, but the cones might be accepted as remnants of an ancient glacial deposit subsequent to the carving out of the over-deepened portion of the valley, which deposit has since been cut up by further denudation.

The two views of the matter are expressed diagrammatically thus (fig. 23) :—

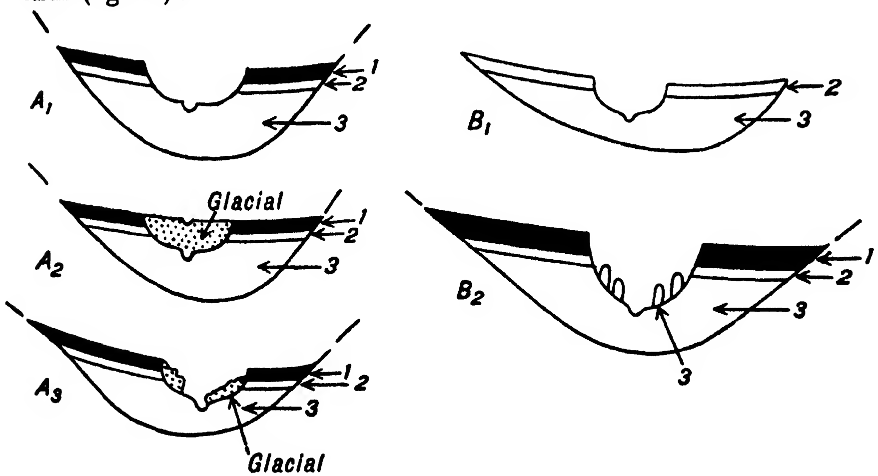

FIG. 23.

A1, A2, A3 show one possible series of events, B1 and B2 show the other. As mentioned above, page 297, B1 and B2 seem the most probable from the evidence of the better exposed sections in the field.

At first sight the above may seem a somewhat long exposition of a small matter; but really it is a point worth a great deal of careful consideration. It cannot by any means be regarded as finally settled by the observations made in 1912.

LAKELETS, PONDS AND POINTS WITH REFERENCE TO DRAINAGE.

Lakelets.

Under this heading will be included all present-day lakelets and ponds, or remains of lakelets and ponds which can be recognised as of very recent disappearance.

Lakelets of Sona glacier.

The Sona glacier shows many signs of recent retreat and there are several small ponds in the sheet of moraine which has been left to line the ancient bed as the ice has retreated. Pl. 38 shows the position of two of these ponds on 6th September 1912. They are small and of the usual type formed in the hollows of morainic material in front of retreating ice. They call for little remark.

The Chingchingmauri glacier shows a very beautiful little lakelet, which lies in a hollow of ancient morainic material. The outflow is over loose rocks. The deposit in which it is formed is probably fluvio-glacial. The hollow looks as if it were formed in the now deserted bed of what was once the Chingchingmauri glacier stream, which latter has been a little diverted by some subsequent accident of erosion. This lakelet is quite small and is only from 4 to 5 feet deep in the deepest part.

A very interesting series of "flats" is seen behind each terminal mound of the ancient terminals of the Ralphu, thus (fig. 24) :—

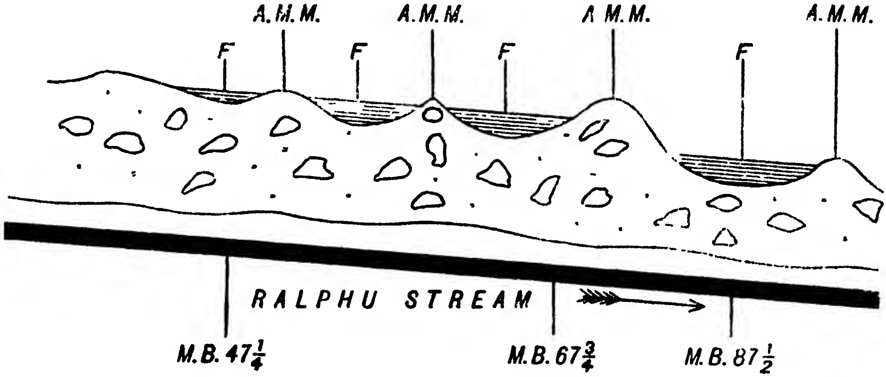

FIG. 24.

AMM ancient moraines (terminals)
F flats formed by subsequent alluvial filling.

The traces of the last meanders of the small depositing streams on these flats are still to be seen in certain lights. The hollows must at one time have held small lakelets.

The above feature lends itself to very clear interpretation in the field, and it seems almost certain that the above view is correct.

Deviation of Drainage (Local).

An interesting example of this is shown in the case of the great "swallow hole" in the left side of the Nipchungkang glacier near station VI. The extra glacial drainage should normally flow down outside the moraine wall, and between it and the valley side, and this sudden breach is somewhat puzzling at first sight. An examination of "snow fans" still left in places, however, explains how the breach in the moraine wall is brought about. The fan acts as an elevator and director, launching the heavy spring freshets of melted snow water on to the ridge of the moraine wall and so starting the attack. Large snow fans occur more or less in the same place each winter, and the attack once started the breaching is continued each spring (see fig. 25).

Snow fans in spring enable attack of ridge of lateral moraine walls to take place.

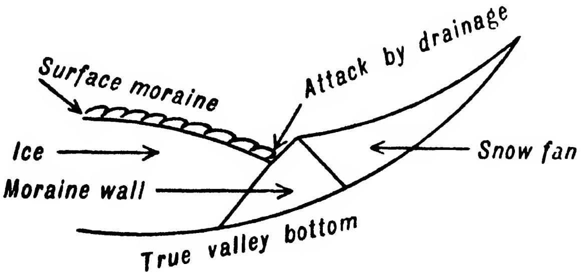

FIG. 25.

The channels cut by the above process are fairly permanent. and can sometimes be noted in the empty bed left in front of a retreating glacier. (For example see the cut near station IX, Nipchungkang glacier.)

FORMER GLACIATION.

Scratched Boulders.

A very careful search in ancient moraines and ancient fluvio-glacial deposits in this area may eventually result in the discovery of specimens of scratched boulders or pebbles. None were seen during this visit of 1912. Such sub-angular or partially smoothed boulders as were seen appeared to owe their shape to the action of water.

High Ice Line on sides of Valleys.

This is a very common phenomenon in this area. It is generally to be noted where rock ridges come down from the valley sides so close to the ice that the latter has been pressed hard upon them and the formation of a moraine wall has not been possible. It sometimes happens that the shrinkage of the ice leaving the high ice line has also made possible the formation of a moraine wall of the present epoch at the foot of the stain of the ancient ice on the valley side.

High ice stain frequently footed by moraine wall of present epoch.

The "High Ice Line" may be seen on the valley side overlooking the left lateral moraine of the Sona glacier. An eye estimate would place the ancient ice level as from 150 to 200 feet above the present level.

Ancient Moraines.

Throughout the whole area visited these are exceedingly common. But even though common, and of a distinctive type, there are in places other accumulations of rock stuff or remnants of former land forms which can, at first sight, be easily mistaken for ancient moraines. This is all the more difficult to recognise in those cases where a certain but small amount of morainic material has subsequently been deposited on forms which approximate in shape to moraine heaps. These are thus partially masked, and rendered of an apparently greater glacial importance than a fuller examination will allow.

The three most important of these deceptive forms are:—

(1) Fans which have been subjected to very heavy freshet-cutting in the spring.

(2) Remnants of the ancient "shelf" which have been subjected to peculiar carving near the entrances of tributary streams into the main valley.

(3) The toes of certain ridges jutting into the main valley.

A single example of each of the above will be described as a type.

These features are of very considerable importance to the observer in the field as they illustrate how completely the eye may be deceived until a land form has been examined from all sides.

Taking them in turn we have—

(1) Fans which have been subjected to very heavy freshet-cutting in spring.

In the valley of the Naulphu glacier is seen the light-coloured denuded face of an accumulation which might easily be taken for a morainic one, occurring as it does just below the ice caves of the Naulphu glacier. It appears, however, on a close inspection that this is really the remnant of a detrital fan which has been cut up by spring freshets.

Cutting power of water in spring.

That the melting snow in spring causes the most extraordinary results is beyond all doubt. Frequent examples of channels cut through fans for long distances in straight lines are everywhere to be seen. They look like the tracks of enormous ploughs, the earth and stones being thrown up on each side of the cut. These cuts grow enormous in some cases, and so slice up the fans that they are hardly recognisable as such. The local drainage eventually seems to settle down into one channel, and the remainder of the fan becomes partially covered with vegetation. It then looks at first sight very like an ancient moraine.

Many examples of such features may be seen on the left side of the Lissar nadi between Sipu village and the Kharsa grazing ground.

Next may be mentioned—

(2) Remnants of the ancient "shelf" which have been subjected to peculiar carving near the entrances of tributary streams into the main valley.

An excellent example of this may be seen in the mound on which Sipu village stands. Coming up the Lissar valley from Marcha, when Sipu village first comes into sight, it seems

almost impossible to doubt that it stands on a huge ancient left lateral, or terminal of the Naulphu glacier. But after closer examination it becomes more and more doubtful that this is the case.

Mound on which Sipu village stands.

Without doubt a considerable amount of morainic material is deposited on the mound. And, moreover, the mound itself may have been originally formed from glacial or fluvio-glacial detritus. But if so, it is probable that these latter were of a very ancient epoch. The mound as it at present stands seems rather to be the remnant of portion of the "shelf" left on the valley side by over-deepening of the Lissar; this "shelf" has been carved down into by the Mula gar on one flank, and scooped out by the Lissar nadi on the other, until it resembles a huge moraine in general outline.

Turning to the third and last set we have—

(3) Toes of certain ridges jutting out into the main valley.

Forms like moraines.

These features might, in the distance, be easily mistaken for huge moraines, more particularly by an observer who has come up into the Lissar valley through the villages of Sona and Dakar, as the forms in question appear in elevation to have very much the same shape as the moraines of the Cholungli glacier.

But it is almost certain that these land forms are really the "dead ends" of ridges jutting down into the Lissar valley. A glance at Pl. 42 (the sketch map of the Kharsa and Chingchingmauri snouts), shows that the ridge, which in Pl. 36, looks like a moraine heap, is really the continuation of the high ridge between the Kharsa and Chingchingmauri glaciers. It is to be presumed that the very distinct shoulder exhibited near station IV indicates that the upper edge of this land feature was once the valley bottom, but that over-deepening and the action of water has shaped it into its present form.

The direction of local drainage off the ridge would tend to leave a spur at its lower end, while cutting away the up valley and down valley faces near its extremity. This spur would maintain for a considerable period the outline of the original cross-section of the valley.

The whole matter has, however, been further complicated by the deposition of undoubtedly glacial detritus in many places on the land form, and also by remnants of ancient rock falls.

The large number of irregular blocks scattered over ridges of this nature require some explanation. The observations made in 1912 cannot be accepted as fully explaining this feature.

A future examination of a ridge of this type near the end of the Ralphu glacier will probably help to throw some light on the matter.

Ancient moraines of Baling Glacier.

These false forms having been noted, the ancient moraines of each glacier visited will be dealt with. The more important of these have been marked diagrammatically by means of dots on the outline sketch map of the area shown in Pl. 40.

Ancient moraines of the Baling glacier.

Taking them in detail those of the Baling glacier are the first to be noted. No survey of the snout of this glacier was made, and by an accident the photograph of its ancient laterals was damaged. Sufficient information has, however, been recorded to give some idea of their extent and shape. The ancient right lateral swoops down from the present ice cave into the bed of the Dhauli river, which must have cut down to within quite a short distance from its present bed before the moraines of the Baling, now visible, were deposited.

Ancient moraines of Sona Glacier.

Sona glacier ancient terminals, "Class A."

These are an exceedingly interesting series, and were examined in some detail. They are shown dotted in Pl. 43 and include at least three well-defined sets of ancient moraines.

Class (A).—Those representing the most advanced position of the ice which can be traced in the field. These are shown near the letters A. T. M. on the bank of the Dhauli river.

It is evident from these moraines that the Sona glacier once delivered right across the present position of the Dhauli river. The problem which still remains for solution is,—did the glacier cross the river, the latter continuing to flow through a tunnel in the ice? or did the glacier dam the river and cause a partial deviation of drainage locally? A very careful examination of the ground covered by cultivation near the villages of Baun and Pilam is needed before a final opinion can be formed. There are certain dry water-courses in this area which might yield some information on the point.

Associated with the advanced terminals, though cut off from them by the Dhauli, are the lower ends of two very well-marked ancient laterals. These may be seen in Pl. 43 near Dhatu and Sona. They are not distinctly visible between the bridge over the Sona stream and the second series of ancient terminals near *κ*. It is possible that they have been removed by denudation on this section. But they may never have been developed. The drainage of the two high sharp ridges on the north and south sides of the valley would have been able to attack them at all points except near Dhatu and Sona. At these two places they jutted too far out into the valley, to offer a target to wash from the valley sides. Their tips have been slightly attacked by the Dhauli river on the north side and indications of the junction between their lower surface and the ancient valley filling can be traced in places there. The tip of the ancient right lateral may or may not be touched by the Dhauli. But it does not appear to have been so attacked.

Sona glacier ancient laterals, "Class A."

All the above moraines of "Class A" are covered with firmly established vegetation.

Class (B) moraines representing either a second pause in the general retreat of the ice, or else the furthermost limit of advance in a stage intermediate between moraines of Class (A) and those of the present day. In Pl. 43 these Class (B) moraines are seen in the more eastern portion of the tree-covered mounds, station *κ*; also, on the north side of the glacier, in the ancient broken left lateral exterior to the more perfect lateral terminating in *ϵ* (see Pl. 38). On the south side of the snout this Class (B) is represented by the outermost of the several lateral walls between station III and station V. In Pl. 38 these may be seen in the lower right hand corner of the picture; the advanced portions of these laterals are here shown and have been marked A. T. M., as they have at this point curved round so much in front of the icefoot as to become, practically, ancient terminal moraines.

Sona glacier ancient terminals, "Class B."

Sona glacier ancient laterals, "Class B."

Class (C) moraines representing a pause of the ice only a short distance in front of the present icefoot. The following are moraines of this class shown in Pl. 43—the left lateral termi-

nating in station ϵ; the "horse-shoe" shaped terminal just west of station κ and the mound forming station κ itself; the innermost of the series of walls in the right lateral near station III and station V.

Sona glacier ancient terminals and laterals "Class C."

The first two of the above may be seen in Pl. 38 at ϵ and near θ.

The present ice level is below these laterals of Class (C) near the margins of the glacier.

There is nothing unusual about the type or cross-section of the above mentioned moraines. The terminals are all of a moundlike, and the laterals of a dyke-like section: provided one makes due allowance for local accidents and subsequent denudation. The "Class A" laterals are the more rounded along the top ridge, which is only natural considering how much older they are than those of Class B or C.

Sona moraines. Type of crosss-section normal.

With regard to the growth of vegetation on these moraines, it may be said to be firmly established on all Class A and B features, and partially on Class C.

Sona glacier, vegetation on ancient moraines.

Ancient moraines of Cholungli Glacier.

These are shown on Pl. 34. The advanced portion of these may be referred to "Class (A)" provisionally. As can be seen on this plate, there are one or two "overlapping ends" of the right lateral at the debouchure in the centre of the panorama. These are so close to the final terminal that they possibly belong to "Class B." But the valley of this small glacier is so steep that the point cannot be decided without a careful traverse right up it. In such a steep valley the actual distances between Class (A) and Class (B) moraines might tend to be much less than in a glacier valley such as the Sona.

Cholungli glacier, ancient terminals and laterals, "Class A."

With regard to type of cross-sections, there is no special remark to make: it was normal where observed in 1912. Grass and bushes are very firmly established on the Cholungli moraines, which indeed are a favourite grazing ground. They are quite visible in Pl. 34.

Cholungli glacier, cross-section and vegetation on ancient moraines.

It is to be noted that the regular rows of light-coloured mounds all more or less parallel to one another, seen on Pl. 34, above Tizang village *are not natural features.* They are heaps of stones and boulders formed by the villagers when clearing the ground for cultivation. The advanced terminal looks very much as if it had been formed by sub-glacial moraine "banking out" and probably is not a "dumped moraine."

Ancient moraines of Naulphu Glacier.

Naulphu glacier, ancient moraines, "Class A." (?)

A very slight examination of this glacier was made. As mentioned above (p. 304) the mound, on which Sipu village stands, looks, at first sight, like an ancient moraine, but is believed not to be one. However, to the west and north-west of Sipu on the top of the shoulder left between the village and cliffs are indications of small ancient moraines. These may be provisionally accepted as the remnants of Class (A) in connection with the Naulphu glacier.

Moraines both of Class (B) and of Class (C) appear to be represented, the latter by the 'ice stain' still visible on the laterals of Class (B). An indication of what is meant by this may be seen on Pl. 30, fig. 2, where above the ice-cave a bare area may be noticed on the moraine wall, above which a grass-grown strip is visible under the bar of mist. This bare area may be classed as (C), the grass-grown strip being (B).

Ancient Moraines of Nipchungkang Glacier.

Nipchungkang glacier, ancient deposits approximating to "Class A."

Quite close to the junction of the Nipchungkang glacier stream with the Lissar nadi there is a series of peculiar earth cones and remnant blocks of an ancient deposit, left by denudation, still sticking to the valley side. These are believed to represent one of two things. Either they are remnants of the lower portions of ancient laterals of the Naulphu, or they are portions of the ancient sub-glacial moraine or valley filling. The deposit is a light-brown mass composed of angular and sub-angular blocks contained in a matrix of compressed light-brown earth. The stones in the deposit higher up the valley are "angular and sub-angular," lower down the valley there is a preponderance of "sub-angular" ones. In some parts of the deposit there are traces of a tendency to bedding, but it is very feeble.

This deposit would require considerable attention in the field to establish its nature for certain. But it appears to be associated with a period of ice extension corresponding with the moraines of "Class A" mentioned in the case of the Sona glacier.

On Pl. 41 the laterals of Class (B) are to be seen near station X in the case of the right lateral and to the north of station X in the case of the left lateral.

Nipchungkang glacier, ancient laterals, "Class B."

The ancient terminals of this period have been removed by subsequent denudation, unless the spur on which station X is situated be accepted as representing them.

The laterals of this class have suffered very considerably from "valley side sweeping." It is quite probable that they will eventually be traced further down the valley than station X, but the stone chutes shown in this area are very active and have smothered them so much in places that the true termination of the series is hard to locate.

Nipchungkang glacier, ancient laterals and terminals, "Class (C)."

Laterals and terminals of Class (C) are to be noted on Pl. 41 due south of station II; they are easy to recognise. The same features are also well shown in Pl. 31, fig. 2.

The number 3 under station III is rather faint as seen in the photograph, but is quite recognisable as a distinct feature in the field.

Nipchungkang moraines, duplication of laterals.

As will be seen by glancing at Pl. 41 the right and left lateral moraine walls are composed of two members each. They are both well above the present level of the ice at the sides of the glacier. These two members are well seen in Pl. 32, fig. 1. Station II is situated on the crest of the outer one. Certain small subsidiary laterals appear to be traces of minor fluctuations or pauses of the ice.

The members 1 and 2 are the important ones to note, as this double wall is also a feature of the Kharsa glacier which will be noted further on.

Yet another interesting series of moraines is the complication near station VIII. This is shown roughly on Pl. 41. The series is due to deposition from a small tributary glacier of a most rudimentary kind which enters the Nipchungkang from the right

side of the valley not far above station VIII. It may be presumed that this complication indicates that the small tributary has participated to a great extent in the fluctuations of the main glacier. The articulation of the moraines as seen near station VIII is very beautiful, and presents an appearance of sympathetic response (so to speak) on the part of the glacier.

Nipchungkang glacier, ancient moraines, vegetation on, and cross-section of.

Vegetation is firmly established on all "Class B" moraines of the Nipchungkang and in places, on the outer slopes of the dykes of "Class C." There is nothing unusual in the cross-section of these moraines.

Ancient Moraines of Dangan and Yamerson Glaciers.

These are the two small glaciers shown in Atlas of India ¼ sheet 66 N.-E. in lat. 30° 21′ N. between the Nipchungkang and Kharsa glaciers. The Dangan is the more southern one of the two. They are small glaciers perched high in small hanging valleys, of the common "arm-chair" type.

The remnants of ancient terminals are of interest as they have been heavily attacked by the Lissar nadi. Pl. 35, fig. 2 shows the series well. The more advanced portions are seen in the trace of an imaginary line passing through the centre of the panorama (marked by the two side "nicks"). The continuation of these may be seen in section in the right upper quarter of the plate.

Pl. 39, fig. 2, shows, diagrammatically, one possible interpretation of the feature seen. The diagram is not to scale and is only an attempt to make something out of the matter as a first approximation.

Ancient Moraines of Kharsa Glacier.

The sketch-map of the snout and moraines of the Kharsa glacier was executed with considerable care.

The ancient moraines of this glacier may be grouped under three headings as in the case of the Sona glacier.

Kharsa glacier, ancient moraines, "Class A."

The terminals round station I near 12630 b. in sketch-map (Pl. 42) may be classed as "A" and the laterals passing station III and that marked "ancient left lateral" just south-east of station XXVI may also be taken as belonging to "Class A."

The "old terminals" near and to the east of station η are "Class B" and are believed to be associated with the outer of

the two members of the "present laterals." The so-called "present laterals" are each composed of two members both of which are considerably above the present level of the ice at the edge of the glacier.

Kharsa glacier, ancient moraines, "Class B."

The articulation of the "Class B" laterals with the "Class B" terminals is not well shown on the sketch-map. In the field it is in a measure marked by a small drainage channel just south of station η, but in the photograph (Pl. 33, fig. 2) the association can be traced with ease.

The inner of the two members of the "present laterals" thus become "Class C." The terminals of this series are quite small, though no doubt some portions have been removed by the glacier stream.

Kharsa glacier, ancient moraines, "Class C."

The remnants may be seen in Pl. 33, fig. 2 (1·2 inches from left edge and 1·1 inches from top). In the original photograph, of which this plate is a reproduction, it can be at once recognised, with the assistance of a reading glass, that these "Class C" terminals have been shot out over the upper ends of the "Class B" ones at this point. Shrubs, etc., are firmly established on these latter while "Class C" ones look raw and light in colour compared with them. They are also to be seen on Pl. 33, fig. 1. The beautiful white wall of the left lateral of "Class C" is also well seen.

Ancient lateral moraines of the present epoch are now forming inside those of "Class C."

The cross-section of all the "formed" moraines and dykes is quite normal. A slight variation from the usual form of terminal mound may be noticed near station η. These mounds exhibit a cross-section of the "crested wave" form (see fig. 26).

Kharsa glacier, ancient moraines, cross-section.

FIG. 26.

The steepness of the septum, it is believed, has been caused in the first place by the fact that it represented the surface of contact with the ice shortly before the time of a somewhat sudden withdrawal of the same. The face has probably been steepened and the slope reversed by the action of the small inconstant stream at "b." The general slope of the ground being from "a" towards "c," this stream would tend to undercut the septum. But the action would be very gradual on account of the stream being inconstant and the slope from "a" to "c" very gentle. The form of the above mentioned terminals are shown on Pl. 33, fig. 2, and the ruling lines of the "crested wave" form have been picked out for illustration in the field sketch (Pl. 37).

Kharsa glacier, vegetation on ancient moraines.

Good grazing and juniper are firmly established on "Class A" moraines: see Pl. 35, fig. 2, which shows the ancient terminals.

With reference to "Class B" moraine, as has been mentioned above (p. 311), shrubs are firmly established on the terminals of this class, *see* Pl. 33, fig. 2. The "Class C" moraine walls (*i.e.*, the outer of the two members in each case) have bushes and grass growing on them in places, but by no means everywhere. There are long strips without any vegetation, or with only a very little.

Another series of moraine-like mounds touching the right lateral are also grass-grown, but they do not seem to belong to "Class B" nor to the moraine wall; they are probably terminals from what was once a small tributary glacier in the gully full of snow leading down towards them. This point is, however, uncertain as a near examination of them was not made.

Ancient Moraines Chingchingmauri Glacier.

These are very roughly indicated on Pl. 42. As the survey has been rather general, it is not advisable to class any of the features rigidly as "A," "B" or "C."

One of the moraine walls is very similar in shape and relative position to that of the Kharsa glacier running from station III to station II and so may be provisionally presumed to represent a similar pulsation of glaciation. It is believed that the terminals some 400 to 500 yards north-west of station XX are ancient ones belonging to the Ralphu glacier and not to the Chingchingmauri.

Near station XXIII the ancient left lateral shows a distinct tendency to deploy.

Between the horns of the ancient laterals there are a few degraded mounds, cut by the stream and smothered in fluvio-glacial deposit. They are, however, small terminals without doubt. One long, low, lumpy series looks as if it was really the remnant of a small lateral formed on the north (left) side of an ancient lobe thrown out from the "right front" of the glacier foot, but the feature has been much altered by running water. No attempt has been made to show this on the sketch-map.

Chingchingmauri glacier, ancient moraines, vegetation on.

All the above moraines are more or less grass-grown. Inside the grass-grown lateral moraines are others, younger and bare.

Chingchingmauri glacier ancient moraines "Class A, B and C."

Without entering into great detail, it may be said that the Chingchingmauri ancient moraines roughly exhibit the same grouping as those of the Kharsa. That is to say, they may be classed as "A, B, C." Since the details on the sketch-map are too rough to show these points, while references to my photographs would involve much complicated explanation, I may perhaps leave the matter and content myself with remarking that this grouping into three classes of moraines, other than those of the present epoch, seems quite clear in the field to an observer who has just arrived on the ground from the Kharsa area. In this latter area the three groups are clear, as has been explained above (pp. 310 to 312).

Chingchingmauri glacier, cross-section of moraines of usual type.

There is nothing unusual about the type of cross-section exhibited by the moraines of the Chingchingmauri glacier.

Chingchingmauri glacier, sub-glacial moraine tending to bank.

There is, however, one point worthy of note about the sub-glacial moraine. The glacier is "banking up" on this feature. There is at present no very evident protrusion of the embankment into the Lissar valley: but there is so to speak a tendency to protrude as well as to "bank up." As has been noted above (p. 307), this is a feature of the moraines of the Cholungli glacier near Dakar. Thus, though the Chingchingmauri valley hangs over the present valley bottom, and over the immature shelf, still at the same time the appearance of hanging is rendered greater by this banking.

Of course the embankment need never develop into a protruding one. For though the glacier may be overloaded sufficiently to drop spoil for embanking at its present rate of diurnal motion, should a secular advance take place, it *might* be accompanied by an increase of diurnal velocity. In this case the load might be held instead of being dropped, and would go forward till extruded at the upper surface or sides of ice and eventually would form a dump terminal.

Ancient Moraines of Ralphu Glacier.

The remarks on p. 300 with reference to the flats formed in rear of these terminals of the Ralphu are the only ones worthy of record. The glacier itself was not examined.

FLUVIO-GLACIAL DEPOSITS.

It was quite impossible, during the visit of 1912, to study the great deposits in the main valleys, now cut into by the Lissar and Dhauli. These may, and probably in places do, contain fluvio-glacial detritus of a very ancient epoch. The only fluvio-glacial features which were noted were those very evident ones which belong to epochs approximating to those in which moraines of "Classes A, B and C" were formed. These may be scheduled roughly as follows:—

Glacier.	REMARKS.
Sona glacier . . .	A "valley train" extending from the present ice cave down to the mouth of the Sona valley. The type is normal, though somewhat immature. It is uncertain how much of the aggrading of the mouth of the valley in ancient times is due to fluvio-glacial or fluviate detritus. The possibility of sub-glacial embanking having taken place between the horns of the ancient moraines at Dhatu and Dhaktu should be kept in mind.
Naulphu glacier . .	No very definite fluvio-glacial train. Fluvio-glacial matter in the bed of stream.

Glacier	REMARKS.
Nipchungkang glacier .	A small train from the ice cave down to near station X.
	The cones and earthy deposit at the mouth of the valley (see p. 308) may possibly be partially fluvio-glacial in origin.
Cholungi glacier . .	Some portions of the upper beds of the fan at the mouth of this valley are fluvio-glacial—namely, those parts which have been brought down through the gap in the ancient moraines kept open by the stream.
Dangan and Yamerson glaciers.	Much of the detrital matter masking the ancient terminals of the glaciers.
Kharsa glacier .	Some of the upper beds in the flats round station III. It is possible also that a very large section of this formation has been removed by the over-deepening of the Lissar.
Chingchingmauri glacier .	Everywhere in front of the present ice cave right down to the Lissar nadi are lines of fluvio-glacial detritus partially masking ancient moraines. Many of the latter have been cut up and rearranged further down hill near the small lakelet at station XXV.
Ralphu glacier . .	The flat in rear of the ancient terminals as mentioned above (p. 300).

ICE AND OTHER FEATURES OF THE GLACIERS THEMSELVES.

Colour of Glacier Ice.

Notes on the colour of the ice were taken on seven occasions.

Poting ice as a "standard."

The ice as noted at the ice cave of the Poting glacier, Kumaon Himalayas, June 1911, was accepted as a sort of standard of comparison (see *Records, G. S. I.*, Vol. XLII, p. 107 sqq.).

TABLE F.—COLOUR OF ICE.

Extracts from field notes.

Glacier and point of observation, date, etc.	REMARKS.
I. Baling glacier ice cave, 3 P.M., 5th September 1912.	Much less "developed" than "Poting ice." Ice white, owing to much included air. No "dark" ice seen. Some blue in parts.
II. Sona glacier ice cave, about 12 P.M., 17th September 1912.	Ice may be classed under two headings as to colour :— (*a*) *On right side* (S. W.) near first break towards ice cave, white air-filled ice with some blue plates as usual. Much less mature than "Poting ice." (*b*) *On left side* (N. W.) ice clear and dark to look into, with practically no air. Much more developed than any other ice seen in Lissar nadi or Dhauli glaciers. Very much more of the "Poting type" than any other ice in this area. This clear and more or less dark ice believed to extend into the "dead end" of ice on north-east side of snout.
III. Naulphu glacier in cave, 4 P.M., 8th September 1912.	Less mature than "Poting ice."
IV. Nipchungkang glacier in cave, 1-30 P.M., 10th September 1912.	Ice very "immature." Very white in most parts. Appearance much more like advanced névé than ordinary glacier ice such as one would expect to find at the ice cliff. Much less mature than "Poting ice."
V. Nipchungkang glacier above III near entrance of small tributary glacier, 11th September 1912.	Ice from tributary glacier and also that in main stream examined and both found to be white, air-filled and immature. (*Note.* This is not "ice as seen at ice cave" and so is not comparable with "Poting ice.")
VI. Kharsa glacier ice cave, 12-20 P.M., 13th September 1912.	Ice full of air, white, even the blue plates contained some air tending to render them of a less intense blue in colour than would otherwise have been the case. Not so mature as "Poting ice."
VII. Chingchingmauri glacier ice cave, 12 noon, 14th September 1912.	Much the same as at ice cave of Kharsa glacier, but ice not well enough exposed to allow of a really good observation being made. Not so mature as "Poting ice."

As can be seen from table F above, with only one exception, all the ice in the ice caves and at the icefoot of glaciers in question is white in colour as seen under ordinary circumstances. This does not mean of course that there are no blue parts, nor stripes of darker ice. But taken as a whole the general look is white. This is due to the presence of a very large number of bubbles of air throughout the mass. The ice is quite different in this respect from that seen in the ice cliff of the Poting glacier in 1911. In that case the ice was normally grey as viewed from a distance, and the white look (with grey ribbon stripes) could only be seen under special lighting, or from a special angle of view. This is by no means the case in the Lissar-Dhauli glaciers.

White ice compared with grey "Poting type" of ice.

Repeated attempts to obtain a generally grey look or a change in colour of any sort were made by shifting the point of observation on many occasions, and under various lights. No change in appearance of any sort was obtained.

The only exceptional ice met with was that mentioned in table F, section II (*b*); and as will be recognised later this ice also presented other points of difference from the "white ice" seen elsewhere.

It is to be noted that the ice at the cave was observed in each case (for comparison with that of other glaciers), as this is one of the few "points of correspondence" which can be selected without a cumbrous survey of the whole glacier.

Structure of the ice.

The structure was examined wherever ice was traversed. The following extracts from field notes are taken as types sufficiently varied to include all cases observed. For purposes of comparison "Poting ice" at the ice cave has been taken as a standard.

TABLE G.—ICE STRUCTURE.

Extracts from field notes.

Glacier, point of observation, etc.	REMARKS.
I. Baling glacier ice cave.	Structure approximating to the "Alpine type." White air-filled ice with included blue bands. Dark bands something like Poting type "ribbon stripes" running with the structure.
II. Nipchungkang glacier above VIII near small tributary glacier.	(*a*) *Ice from tributary glacier.* The ordinary forms of structure not developed. The stratification was visible *as such*, that seen in the glacier being traceable back to the small steep névé bed from which the ice is derived. (*b*) *Ice in the main stream.* Ice "immature," lamination somewhat hard to observe but existing. White ice with zones of clear ice. Lamination traceable in hand specimens in some cases. Blue plates $\frac{1}{2}$ inch to $\frac{3}{4}$ inch thick, white parts $1\frac{1}{2}$ inch to 2 or 3 inches thick. The blue in long streaks compared with its length, running from 6 inches up to 2 or 3 feet in length. In addition to the above there are in places great seams of clear ice 3 inches to 6 inches wide and of great length In these seams dirt collects in very clearly defined planes.
III. Kharsa glacier ice cave.	Lamination distinct, also certain slight ribbon stripes approximating to Poting type, but very irregular.
IV. Sona glacier ice cave.	(*a*) On north-east side of cave (left) ice laminated more or less in the manner of "Poting ice cave" ice but the grains not compressed quite so much. Lamination "short" and consisting of plates of clear ice contained in other ice not so clear. (*b*) On south-west side of cave (right) lamination more of Baling and Kharsa type, ice white, blue plates, very immature and ill-defined ribbon stripes.

The ice caves.

Summing up the notes in table G as a whole: the structure of the ice at the ice caves of the Lissar-Dhauli glaciers is of a less advanced type than that presented at the ice cave of the Poting glacier. There is, however, one exception, namely, the ice in the "dead end" on the north-east (left) side of the Sona cave.

Ice at caves of Lissar-Dhauli glaciers more like Alpine type than Poting glacier ice.

The Lissar-Dhauli type of structure approximates to the Alpine type in so far as it consists of the interlamination of white with blue or clear ice. This lamination, however, is immature; it is not so highly developed as one would expect to find at the ice caves of glaciers of the length of these in question. But it must always be kept in mind that there seem to be several sets of planes in which structure of one sort or another is presented. It is, therefore, quite possible for the ordinary structure, exhibited by the alternation of white with blue or clear ice, to be immature, and at the same time for it to be crossed (it may be at a very small angle) by another set of planes of some other sort of structure which is highly advanced in its own way.

Direction of structure and other marks on ice.

The next point to be considered is the direction of the structure.

Direction of structure observed at ice cliffs only.

As can be seen from many of the photographs the snouts of all glaciers in this area are so covered with surface moraine that systematic examination of the direction of structure would only be possible at the cost of very great labour and time. For this reason an examination of the outcrop on the surface of the ice cliff was the sole kind of observation made on this point.

The following photographs should be examined in the sequence given :—

Pl. 30, fig. 1	Sona glacier.
Pl. 30, fig. 2	Naulphu glacier.
Pl. 31, fig. 2	Nipchungkang glacier.
Pl. 32, fig. 1,2	Do. do.
Pl. 33, fig. 2	Kharsa glacier.

Sona glacier. Pl. 30, fig. 1. If we examine the bare faces of ice shown in the original photograph with a lens, first in the left centre of the picture, we find ice of the kind mentioned in (*b*) IV of table G above. It will be seen that the lamination here is often folded, crushed and squeezed together. But the plications are distinct in many places and are easily recognised. Masses of less folded ice are included here and there.

Turning next to the ice over the ice cave proper, and again examining it with the lens we notice the ice mentioned in (*a*) IV table G. It will be seen that the structure presented is of a much more regular kind. The face of the ice is divided up by some sort of shear planes. The more refined streakiness of the ice follows the lines of the shear planes or if it does not do so, the angle between the two sets must be very small. The slight compression of the grains themselves does not, however, seem to follow the other two very closely.

In both the above specimens the "spooning" of the main lines of bedding at the end of the Sona glacier are traceable. But in the former case the spooning is in the larger features, *i.e.*, between shear plane and shear plane; or between fracture and fracture (as in fig. 27, "a"). But in the latter specimen the spooning is shown more or less by every sort of line exhibited by the ice (as in fig. 27, "b").

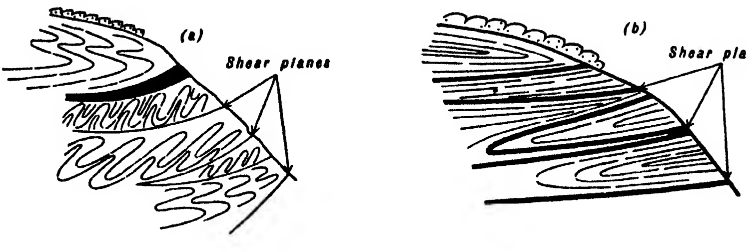

FIG. 27.

But even in "a" there is a distinct, and frequently a very marked, tendency for the folds to become recumbent and to lie roughly parallel to the longer features of the spooning.

Naulphu glacier. Pl. 30, fig. 2. Note the folding in anticlinal form, but partly overfolded, on top of the ice cave. The minor harmonic folds visible in the Sona glacier are absent here. The crevassing on the face is independent of the structure, being partially due to "mushrooming" on impact and partially to gravitational pull over the cave. It is most important to bear in mind that the two branches of the Naulphu do not now meet (1912).

The Nipchungkang glacier. Pl. 31, fig. 2, Pl. 32, figs. 1, 2. If we examine Pl. 31, fig. 2, with a lens, we find that spooning is evident. There is also a very distinct tendency for shear planes (and crevassing of a minor degree) to strike downwards from left to right (as viewed in the picture). The ordinary fluting from surface melting is also very distinctly seen. This latter, in a measure, hides the next feature to which it is desired to draw attention. On Pl. 32, fig. 1, near a point 1·1 inch from the left edge and 1 inch from the bottom, it will be seen that there is shown here a structure of the nature of cleavage. This is well shown by the manner in which the small pieces of ice break away along the edge of the arch of the cave. The eye is at once reminded of the entrance to any small cavern in rock which has been subjected to pressure, developing slaty cleavage in more than one set of planes. The planes in which this cleavage is strongest are those parallel to the white streaks shown in this figure just above the point given for examination. Pl. 32, fig. 2, shows that these latter streaks in the photograph are not due to light and shade effects from the surface of fluting.

In this figure, at 1·5 inch from the left edge, and 1·75 inch from the bottom, the above-mentioned cleavage can be seen tc outcrop on the slanting roof of the cave in planes parallel to those in which it is shown near the lip, and in the white streaks.

The Kharsa glacier. Pl. 33, fig. 2. Here the spooning is most distinct and the minor streakiness also follows the more defined sets of planes.

As is noted in II, table H, the grains themselves show some compression (though not much) in the ice cliff of this glacier.

Granulation of the Ice.

The following are some generally characteristic field-notes on this point :—

TABLE H.

Extracts from field-notes.

Glacier, point of observation, date, etc.	REMARKS.
I. Nipchungkang glacier, 11th September 1912.	(*a*) Ice from small tributary glacier, near junction with main ice stream. Some granulation, size not measured. Some compression of grains ? (*b*) Ice in main ice stream. Granulation noted, " fine lines " on faces of weathered grains proving that grains are set at random. No compression. Size of granulations small. See sketch (*a*) on p. 323 of granulation (natural size) as cropping out on surface. " Worm-like threads " deep set in ice prove that melting from surface of each grain is going on at some depth in ice, though of course relatively near surface.
II. Kharsa glacier, at the ice cave. 12th September 1912.	Granulation at the termination of Kharsa glacier at about the same stage of development as that viewed in 1911 on Poting glacier in ice which had fallen in blocks down the ice fall. The size and type of interfelting of the grains is shown in the full size sketch (*b*) on p. 323. Grains show some compression but not much Worm-like threads noted in mass of ice These show commencement of melting between grains.
III. Sona glacier ice cave, 17th September 1912	Ice on the north-east (left side) of ice cave and in cliff over ice cave (This is the more mature 'Poting' type of ice noted above with reference to colour and structure.) The grains are not compressed to any great extent, and certainly very considerably less so than at the actual termination of the Poting. There is, however, some slight compression and it " follows the structure." The size of the granulation is shown in sketch (*c*) p. 323.

The following sketches (fig. 28) are from careful, full-size drawings done on the spot, the note-book being placed on the ice close to the specimen selected, while the drawing was being

done. Measurements to control the size were frequently made by direct transfer from a template.

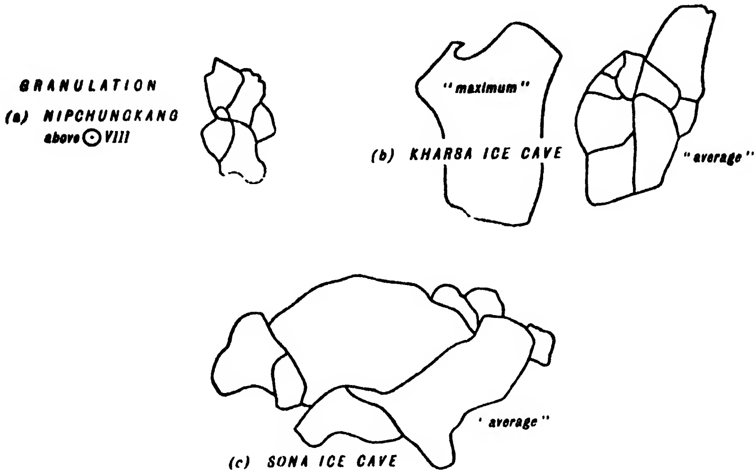

FIG. 28.

The average size of the Sona "dead end" ice granulation and that at the ice caves is greater than that in the case of the Kharsa glacier. It is again noticeable that the undeveloped character of the Kharsa terminal ice as compared with the Sona specimen is shown by this granulation. The fracture of the Kharsa specimen is of a somewhat conchoidal nature; this also is a feature of ice such as that noted as having been shot down the cascade of the Poting. The face of the fracture is more nodular than that of a Sona ice cave or Poting ice cave specimen. A reference to *Records. G. S. I.*, Vol. XLII, page 110, will show that at the termination of the Poting the nodular aspect was highly modified by the very predominant compression. In the Sona specimen this compression is much less than in the Poting, but it would appear to be sufficient to modify the fracture as compared with the Kharsa one, though, of course, the different quantity of included air per equal volume of ice might also have a great deal to do with the difference. This Sona snout ice may be taken as the exception in the case of the Lissar-Dhauli glaciers, and the Kharsa specimens may be provisionally accepted as the type (at the terminations) for this series up to and including the Chingchingmauri. It is possible, however, that a certain amount of difference between individual glaciers would

be discovered if the granulation were subjected to a rigorous examination in each case.

Capillary planes and fissures in ice.

In all cases when ice from the ice cliff, or from within one or two feet of the surface of the glacier was examined, small worm-like threads could be seen in it, at, say, one foot or more from the surface; sometimes closer. These (if the specimen was placed in the sun to accelerate melting) could be seen to expand into the usual planes of melting between grains. The melting could be much hastened by conveying the sun's rays into the specimen with a lens. An interesting point with regard to the behaviour of liberated bubbles of air as they passed into the melted brine in these planes between grains was noted. As the worm-threads developed and grew into capillary planes, bubbles of "included air" were set free into them. These bubbles at once (and with considerable velocity) moved across the field of view, if they were engaged in the more or less horizontal planes, and as soon as they came in contact with a more or less vertical one turned up into it, and thus gradually worked their way up to the exposed surface of the ice. Yet at the same time the cohesion between the grains of the ice in which this action was taking place was still very strong. The peculiar point about this is that though the observation was repeated on many occasions no efficient air trap was ever noticed. In every case the bubble, once started, made a successful journey up to the surface. There were occasional delays, but not long ones, in its upward passage.

This observation shows that the circulation of included air can be considerable through the ice mass, at least near any exposed surface. The fact that bubbles can move so freely in the brine, points to the considerable width and intercommunication of the planes of melting. It becomes a possibility that these may widen sufficiently to pass the dimensions usually designated by the term "capillary." Experiments on the modulus of elasticity in ice specimens of this nature would no doubt yield very interesting figures. Another point for examination is the possibility of the brine between the grains exerting a hydrostatic thrust when the planes have become thus enlarged. Even if it cannot be proved that this enlargement and consequently greater freedom of the grains extends deep into the ice,

Delivery of air through planes of melting and possible relation with ablation and secular and seasonal retreat.

it at any rate must have considerable effect on the scaling away of portions of ice in crevasses and at the ice cliff. This might have a very material effect on the rates of secular and periodic retreat or advance. It must govern to some extent the rate of disintegration of the terminator. Again the rate of ablation of the surface might also be some function of the degree of opening of the planes. The latter would control the upward delivery of included air and this action is bound to be connected in a measure with the rate of ablation.

Included air.

The following notes are tabulated; they are selected as good type examples:—

TABLE 1.

Extracts from field-notes.

Glacier, point of observation, date, etc.	REMARKS.
Nipchungkang glacier, 9th and 10th September 1912. Just above station VII.	(*a*) Ice from tributary glacier, near junction with main ice stream. Ice full of round bubbles of air. Even in size and small.
Ditto .	(*b*) Ice from main stream. Bubbles of included air very numerous. Size ranging from about the diameter of the graphite in an ordinary pencil, downwards. The bubbles of different sizes, some elongated and flattened. Some zones of clear ice.
At ice caves . . .	(*c*) Ice full of bubbles and very white as a whole in consequence. General look much more like advanced névé than snout ice such as seen in Poting glacier ice cave, 1911.
Kharsa glacier at the ice cave, 12th September 1912.	Full of air bubbles, even the "blue plates" contain some. Size of bubbles very variable: say from ⅛ inch in diameter downwards. (See also remarks about included bubbles in section above.) On melting the ice in warm water the bubbles literally poured off it, there was so much included air. They caused the surface of the water to bubble like soda water.

The above notes, in table I, call for little remark. They simply confirm the often repeated observation that as a whole the Lissar-Dhauli snout ice is less mature than the Poting type. The large

size of the bubbles in the cave ice of the Kharsa compared with those seen at a relatively earlier zone of the Nipchungkang is a point of some interest. The notes do not mention any degree of elongation or flattening in the case of the bubbles of the Kharsa cave ice. This may be an omission in observation. But it will be noted that the grains in this glacier show little compression (see table H II above). Had the bubbles been much distorted it is believed the fact would have been noted when this latter observation was made.

General remarks on included air.

Crepitation.

This was noted wherever ice containing air bubbles was exposed to melting. It was very intense in all cases; so much so that at times it almost reached a buzzing sound.

Ice flowers.

These were looked for whenever the ice was examined, but were not noticed. On one occasion only (in ice from the snout of the Kharsa glacier) some small ones were made by heating the inside of a large grain with a lens. They were very minute and of the normal type. No "click" on formation was heard as the local sounds were many and intense.

Sand cones and "Tables."

As a general rule the heavy surface moraine on the lower parts of the terminator prevented the formation of sand cones or glacier tables. A few sand cones of the usual type were seen just above station VIII in the Nipchungkang glacier.

As the upper, less encumbered, reaches of the ice streams were not examined, these two phenomena, if occurring, were, practically speaking, out of the zone of observation.

Temperatures.

Many air temperatures were taken with the sling thermometer for the hypsometrical determination of heights. They are

hardly worth recording in detail from a glacial point of view.

Rough air temperature.

Roughly speaking, the average of 17 observations taken between 9 A.M. and 5 P.M. (local) at heights of from 11,100 feet to 13,700 feet came to 54·8° F.

Stream-water temperature.

In addition to the above, the following series of temperature of stream-waters was compiled. The temperatures were taken with a thermometer which had been carefully compared with standards whose errors were known. They have been corrected accordingly.

TABLE J.—STREAM-WATER TEMPERATURES.

Main streams and junctions.

Place and date.	Altitude above M. S. L.	Temperature in degrees Fahr.	Remarks.	Time (local mean).
	Feet.			
I. Junction of Kali and Gori rivers near Askot, 31st August 1912—				
Kali R. . .	2,210	59·5	Near shore .	2-25 P.M.
Gori R. . .	..	59·0	Do .	2-25 P.M.
II. Nyu (by Sobala), 3rd September 1912				
Dhauli R. .	5,370	51·5	Do.	4-55 P.M
III. Junction of Sona glacier stream with Dhauli R., 7th August 1912—				
Sona stream water	10,110	36·7	Do. .	4-10 P.M.
IV. Tezang Bridge, 16th September 1912—				
Lissar nadi water	about 10,400	40·6	Do .	10-10 A.M

The following temperatures of the glacier streams themselves were also recorded:—

TABLE K.—TEMPERATURES OF GLACIER STREAM WATER.

Taken at point of issue from the ice cave in all cases.

Glacier and date.	Height of ice cave above M. S. L.	Time (local mean).	Temperature in degrees Fahr.	REMARKS.
	Feet.			
Sona glacier, 6th September 1912.	11,090	4-10 P.M.	32·2	..
Naulphu glacier, 8th September 1912.	13,110	4-10 P.M.	34·2	After a night of rain.
Nipchungkang glacier, 10th September 1912.	12,670	3-40 P.M.	32·9	After some little rain.
Kharsa glacier, 13th September 1912.	12,510	1-10 P.M.	32·2	..
Chingchingmauri glacier, 14th September 1912.	13,690	12-10 P.M.	32·1	..

Moraine material.

Baling moraines, huge blocks of white quartzite.

The size of the morainic material is very variable between glacier and glacier, but fairly constant in each case. That of the Baling glacier exhibits by far the largest dimensions. Its moraines are composed of very large boulders mixed with smaller stones, but not very much earthy matter compared with other places of this area. The moraines of the Baling contain much white quartzite rock. The boulders in some cases are huge, say 20 feet by 30 feet.

The Sona glacier shows some very large blocks, but taken as a whole the material would pass a very much smaller mesh than that of the Baling. The white quartzite is not so common.

Materials of other glaciers' moraines.

The moraines of the Naulphu, Nipchungkang, Kharsa and Chingchingmauri are composed of even smaller material than those of the Sona glacier.

A good type example may be selected from the surface moraine of the Nipchungkang about half a mile above station VIII. Here the surface moraine is 2 to 3 feet deep with blocks 2 ft.$\times$1 ft.$\times$1 ft. and $1\frac{1}{2}$ ft.$\times$2 ft.$\times$2 ft. and downwards. There are not many really large blocks.

The materials of these moraines vary from light browns and greys to dark reddish purple. They are such as might be expected from the area in which the cirques lie. The Kharsa shows one bright white left lateral of fine earthy material. As a rule there is a slight tendency for the material of lateral dykes to be finer than that of terminals or surface moraines, probably because they hold the finer earth better and suffer less from water attack.

Slopes of upper surface of snouts near ice caves.

Towards the ends of these glaciers a few slopes along the surface moraine were measured.

Close to the ice caves this slope varies between 10° to 13° in the Nipchungkang and Kharsa glaciers.

The Chingchingmauri is somewhat less, being about 8°. The Sona glacier, however, is more. It is 20° at the very end, but diminishes up-stream. It is not known what slopes the upper ends of these glaciers show. No longitudinal sections were made.

Slope of sides of moraine dykes, etc.

The slopes of the sides of "formed" dykes vary between 30° and 40°. Sometimes where undercutting has taken place they may be a little steeper.

Bedding of moraines.

Bedding was not noticed in any true dykes or terminal heaps, the mass being quite irregular. Slight traces of bedding were seen in the deposit at the mouth of the Nipchungkang glacier valley, as mentioned above (page 308).

Névé—General observations.

No close examination of these was made. But one or two rough clinometer observations were taken to determine the upper

limits of the true snow-fields. Bergschrunds are not large nor easily seen on the north-east side of the Panchchula range. But the approximate upper limits of the névé fields can be located by eye.

On the south-west side of the range Bergschrunds are very large and well defined. One on Takachul is visible to the naked eye at a distance of 17 miles on a clear day.

TABLE L.

Névé and snow-fields ; upper limits of a rough series of estimated heights.

Glacier, height of observer at time of observation, etc., etc.	Approx. distance from point of observation to edge of snow-field.	Rough clinometric slope to edge of snow-field.	Approx. height of edge of névé of snow-field.
Sona glacier, II, 10,995 .	About 7 miles .	11 ° 12 12 mean.	About 18,720
Naulphu glacier, Sipu V, 11,410.	6 to 7 miles .	12	18,000 to 19,000
Nipchungkang glacier, VIII, 13,740.	About 3·6 miles .	14	About 18,690
Kharsa glacier, XXVI, 13,390.	About 4·85 miles	8½	About 17,090

On Pl. 31, fig. 1 (Sona glacier), at 1·3 inch from the top edge and between 1·5 inch and 3 inches from the left edge, the ice appears dark, and surface moraine and dirt are evident. Above this the field is very white. At 1 inch from the left edge and 1·5 inch from the top the collection of surface moraine is going on, as also at 1·8 inch from the left edge and 1·8 inch from the top. But in the centre and upper portion of the dirty ice the stain seems to be due to extrusion, caused, probably, by crevassing and shift rather than by the lines of flow working up.

Sona glacier névés.

From table L it will be seen that the true névé fields may be said to have their upper limit at between 18,000 and 19,000 feet, the peaks above them running up to well over 20,000 feet and in one case to over 22,000 feet.

On the Atlas of India ¼ sheet 66 N. E. the "shoulder" under the main peaks is well shown, but the extent of the glacier

and the névé is much understated. It is really a large glacier for this area; and probably has a somewhat greater gathering ground than the Naulphu, Nipchungkang, Kharsa or Chingchingmauri.

Sona glacier larger than would be expected by estimate from atlas ¼ sheet.

The névé of the Naulphu glacier is small, being fed by snow falling from the steep sides of the cirque. The commencement of the ice fall of the southern branch of the glacier is close to the upper limit of the névé. The peak in question is not a triangulated one; hence the clinometric value of the height of the upper limit of it cannot be checked; but it is between 18,000 and 19,000 feet. It should be kept in mind that this southern branch of the Naulphu does not meet the northern one at present (1912).

Naulphu glacier névés.

The size and shape of the north (left) feeder at the head of the Nipchungkang, if such feeder exists, is not recorded. It is hidden by the spur under M. B. $276\frac{3}{7}$. The névés under M. B. $236\frac{1}{4}$ run up to the Ralam pass and commence at some 18,690 feet.

Nipchungkang glacier névés.

The Kharsa névés only run up to some 17,090 feet and thus are considerably lower at the head than those of the other glaciers recorded. This is in a great measure due to the exceedingly steep sides of the cirque. The snow on the peak is fluted. The wall of the "curtain" to the north of the peak seems to be somewhat low compared with that of the Nipchungkang.

Kharsa glacier névés.

Included dirt.

There is no doubt that much of the included dirt seen in these glaciers tends to settle in "layers." But it is not always certain what set of planes these layers of dirt tend to follow.

Dirt may be included under two heads :—

(i) Very fine dirt, probably wind-transported, which is collected on the névé field.

(ii) Coarser matter collected from local sources.

The former (i) colours the névé in layers, and later on when the latter becomes crumpled shows up the plications very well.

The latter (ii) tends to be scattered through the ice generally. But there is no doubt whatever that at times it tends to settle

down into planes. These seem in some cases to be the planes of healing of crevasses and also in some cases shear planes.

Ribbon stripes.

None so well developed as the Poting ones were seen, though in some cases immature ones were noted. These were visible in *all lights* as brown or grey stripes on a white ground. They could not be made to alter their appearance by shifting the point from which they were observed. The Baling glacier showed stripes somewhat more mature than in the case of other glaciers in this area, except perhaps the Sona.

Diurnal motion.

The rates of diurnal flow of the rocks composing the surface moraine were found with a 3-inch transit as follows :—

TABLE M.

Diurnal flow.

Glacier.	Point and map on which shown.	Duration of observation.	Average flow per 24 hours during time shown in column 3.	REMARKS.
Nipchungkang glacier.	Point α map, Pl. 41.	From 10-30 A.M., 10th September 1912, to 9-15, A.M., 11th September 1912.	2·93 ins.	The measurement at point γ of map, Pl. 41, failed, as the mark was blown over by the wind before the second set of sights were taken.
Do. .	Point β map, Pl. 41.	Do. .	4·26 ins.	
Kharsa glacier .	Point γ map, Pl 42.	From 2-40 P.M., 13th September 1912, to 11 A.M., 15th September 1912.	0·525 ins.	

A 3-inch transit is not a very suitable instrument for this work; it is hardly steady enough to stand the high winds often met in

this area. For this reason, if one is used, work should be finished before 2-30 P.M., at which time the wind usually becomes strong up-valley. Differential angles from some reference mark near the plane of the surface of the glacier and some 30° or 40° from the flow stakes taken with a good sextant would be better, unless a 5-inch theodolite happened to be available.

Hypsometrical heights.

These were obtained with an instrument which was compared with the Bombay observatory standards before and after the series of observations. This was done through the kindness of the Superintendent of the Government Observatory, Bombay. The results were marked out, using the daily observations at Muktesar as the values for the lower station. The reduction of the latter to the moment of observation was kindly done by a member of the staff of the Bombay observatory. As the work progressed in the field rough clinometric determination of heights was made from triangulated peaks to prevent gross error at the time of observation passing undetected.

The hypsometrical values of the heights of glacier ice caves have been tabulated together and not in sequence with other points, to secure handy reference; as these are the most important from a glacial point of view.

TABLE N.—HYPSOMETRICAL HEIGHTS.

PART I.—*Various points in valleys.*

	Feet.
Junction of Kali and Gori rivers near Askot—	
(a) Water level	2,210
(b) Upper terrace	2,330
Balwakot, water level	2,330
Darchula, water level	2,690
Khela Syalapanth (Rest house)	4,930
Nyu, water level	5,370
Sela Gat, water level	7,910
,, ,,	7,970
Dhaktu (by Sona) camp	10,540
,, ,, ,,	10,520
Junction Sona glacier stream and Dhauli river, water level	10,110
Sipu village, on mound by chorten in village	11,410
Sipu bridge, water level	11,110
Kharsa encamping ground	12,510

TABLE N.—HYPSOMETRICAL HEIGHTS—*contd.*

PART I.—*Various points in valleys*—contd.

	Feet.
Kharsa I (see Pl. 42)	12,630
Chingchingmauri camp (see Pl. 42)	13,220
Junction Nipchungkang glacier stream and Lissar nadi .	11,500

PART II.—*Ice caves.*

Baling glacier, ice cave	10,660
Sona glacier, ice cave	11,090
Naulphu glacier, ice cave	13,110
Nipchungkang glacier ice cave	12,670
Kharsa glacier, ice cave	12,510
Chingchingmauri glacier, ice cave	13,690
(See note on map, Pl. 42, with reference to this height.)	

PART III.—*Various points on glaciers.*

Nipchungkang glacier, station III	13,770
,, ,, ,, do.	13,710
,, ,, ,, II	12,760

Field-sketches.

These were done on the plane-table with a *camera lucida*. The magnetic bearings were taken with a 2-inch prismatic compass. The centering error of this instrument had been very carefully found and all observations have been corrected to the nearest $\frac{1}{4}$ degree. A stand was used when taking observations for field-sketches. The clinometer heights are rough. They were taken with a $2\frac{3}{4}$-inch Watkin pocket clinometer. This was carefully tested for index error before and after the series of observations, and the required correction has been applied to all observations.

One may expect a probable error of some $\frac{1}{2}$ degree under the conditions of observation. These clinometric heights are only meant as a rough guide for picking up points again. They have also been used to get a few approximate heights on the sketch maps.

EXPLANATION OF PLATES.

PLATE 30.

FIG. 1.—Northern feeder of Sona glacier and ice cave from ⊙ V.

FIG. 2.—Naulphu glacier (north branch) from Naulphu ⊙ *a*. Ice cave on 8th September 1912.

EXPLANATION OF PLATES—*contd.*

PLATE 31.

FIG. 1.—Snout of Sona glacier from Sona ⊙ α.

FIG. 2.—Position of ice cave on 10th September 1912 from Nipchungkang ⊙ X.

PLATE 32.

FIG. 1.—Position of ice cave on 10th September 1912 from Nipchungkang ⊙ IX.

FIG. 2.—Position of ice cave on 11th September 1912 from Nipchungkang ⊙ II.

PLATE 33.

FIG. 1.—Snout and ice cave of Kharsa glacier on 13th September 1912 from Kharsa ⊙ η.

FIG. 2.—Kharsa ice cave on 15th September 1912 from Kharsa ⊙ β.

PLATE 34.

Ancient moraines of Cholungli glacier near Dakar and Zegany.

PLATE 35.

FIG. 1.—Looking up the Dhauli valley from Dakar village at the junction of the Lissar nadi and Dhauli river.

FIG. 2.—Ancient terminals of the Kharsa glacier in foreground and Dangan and Yamerson glaciers behind, looking down the Lissar nadi from Kharsa ⊙ I.

PLATE 36.

Snout and ancient moraines of Kharsa glacier looking up Lissar nadi from Kharsa ⊙ I.

PLATE 37.

Position of ice cave on 13th September 1912. Field-sketch from Kharsa ⊙ β.

PLATE 38.

Snout of Sona glacier, 6th September 1912. Field-sketch from Sona ⊙ III.

PLATE 39.

FIG. 1.—Naulphu glacier, field outline sketch of lower ice cave.

FIG. 2.—Sketch of Dangan glacier (diagrammatic).

PLATE 40.

The glaciers of the Dhauli and the Lissar Valleys, Kumaon Himalaya.

PLATE 41.

Plane table sketch map of the snout of the Nipchungkang glacier.

PLATE 42.

Plane table sketch map of snouts of the Kharsa and Chingchingmauri glaciers.

PLATE 43.

Rough eye sketch map of the snout of the Sona glacier, September 1912.

MISCELLANEOUS NOTE.

Correction in Nomenclature of two Indian Fossil Mammals.

MR. R. LYDEKKER has drawn my attention to the fact that in adopting as the specific name of a Rhinocerotid species that of *gajensis*, which Mr. Lydekker had formerly applied as a varietal designation for the same species, I have inadvertently described it as a new species. The description in question occurs in the author's memoir on the Vertebrate Fauna of the Gaj series in the Bugti Hills and the Punjab, *Pal. Ind.*, new series, vol. IV, mem. 2 (1912), p. 28, where the species is described as *Aceratherium gajense* n. sp. Since Mr. Lydekker originally described this species under the name of *Rhinoceros sivalensis* Falc. and Caut. var. *gajensis* Lydekker in *Pal. Ind.*, series 10, vol. II (1881), p. 40, the correct designation of the species should be *Aceratherium gajense* Lydekker sp.

I may also mention here that Mr. Lydekker's name of *Propalæomeryx* has the priority over that of *Progiraffa*, originally proposed by myself for a mandible from the Bugti Hills described under the name of *Progiraffa exiqua* in *Rec. Geol. Surv. India*, vol. XXXVII (1908), p. 155, if I am correct in referring the upper molar described by Lydekker under the name of *Propalæomeryx sivalensis* in *Pal. Ind.*, series 10, vol. II (1883), p. 173, to the same genus as the Bugti mandible. In my memoir on the Fossil Giraffidæ of India, *Pal. Indica*, new series, vol. IV, mem. 1 (1911), misled by the circumstance that Lydekker at a later date merged his genus *Propalæomeryx* in *Palæomeryx*, I lost sight of the priority of the earlier name over that proposed by myself. Of course should the upper molar of *Propalæomeryx sivalensis* be subsequently shown to be generically distinct from the mandible of (*Progiraffa*) *exiqua*, then the name *Progiraffa* must stand for the latter, but meanwhile the generic designation of both should be *Propalæomeryx*.

[GUY E. PILGRIM.]

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Fig. 1

Fig. 2

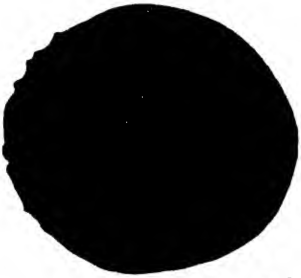


Fig. 3

Fig. 4

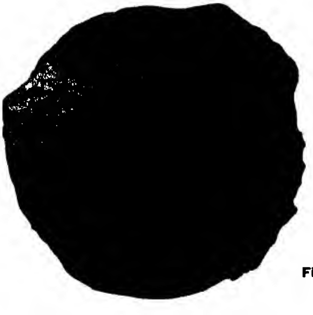


Fig. 5

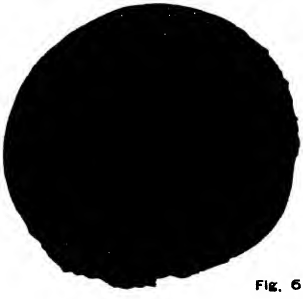
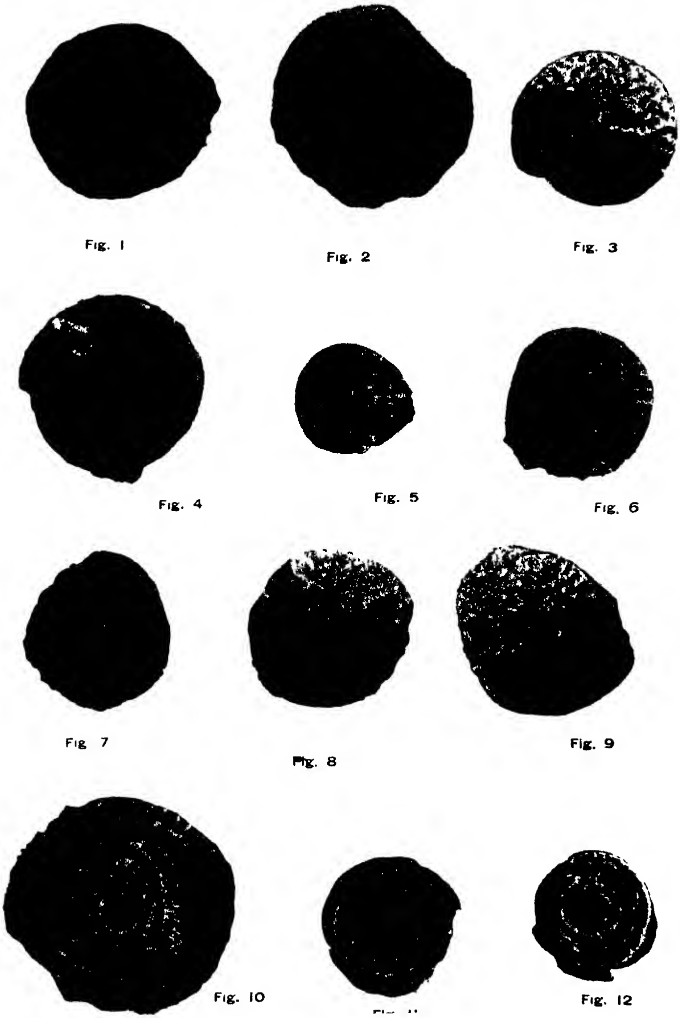


Fig. 6

From Photographs by G. de P. Cotter

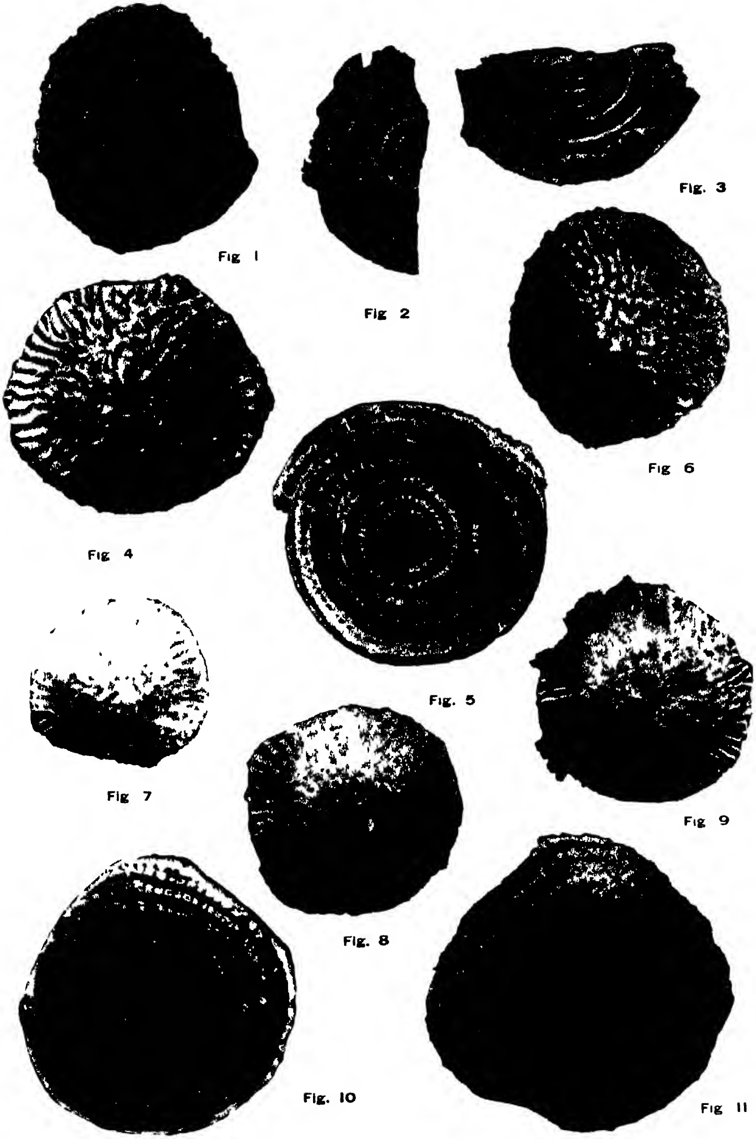
G. S. I. Calcutta.

NUMMULITES YAWENSIS n. sp.
from Yaw Stage, Pakokku district Burma.



From Photographs by G. de P. Cotter. *G. S. I. Calcutta.*

NUMMULITES YAWENSIS n. sp.
from Yaw Stage, Pakokku district Burma.

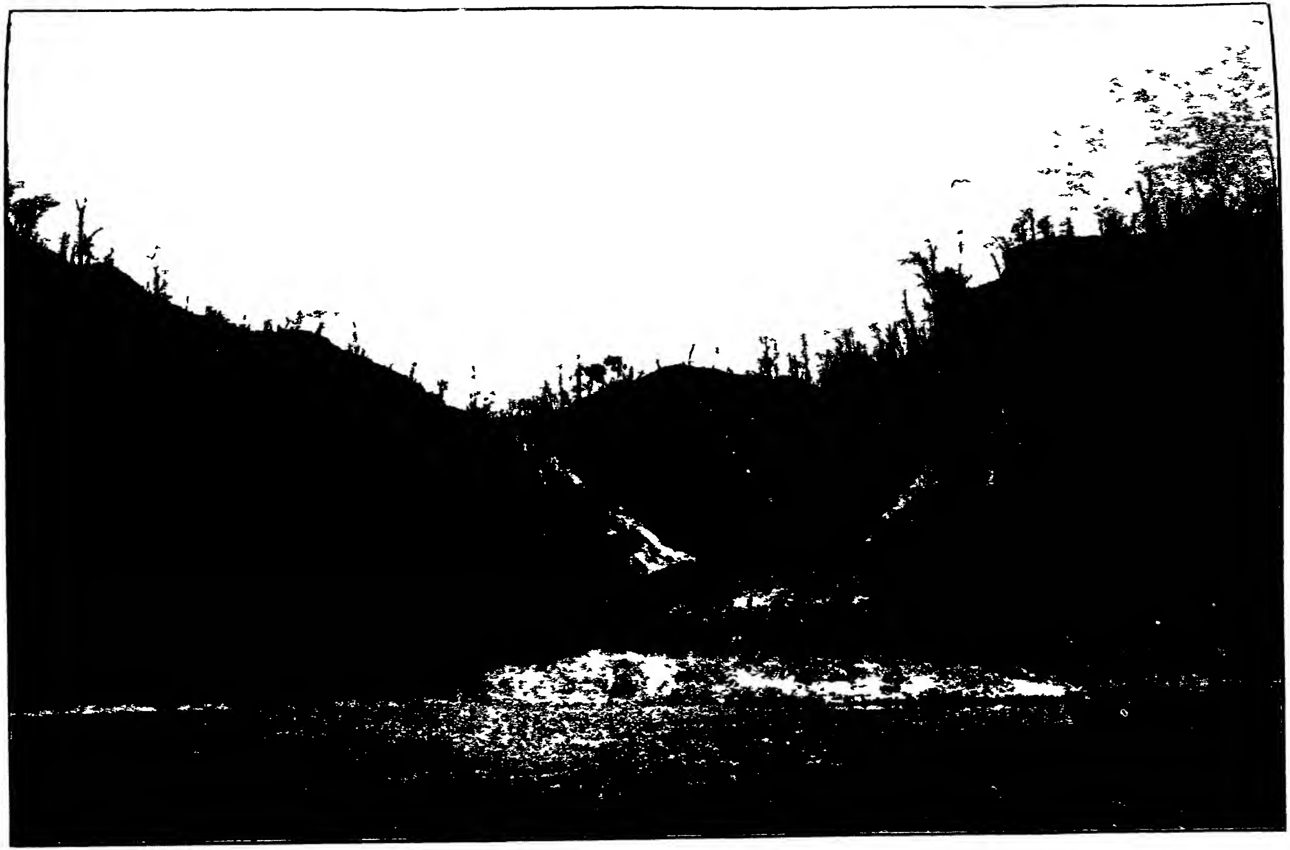


rom Photographs by G. de P. Cotter. *G. S. I. Calcutta*

NUMMULITES YAWENSIS n. sp.

from Yaw Stage, Pakokku district Burma.

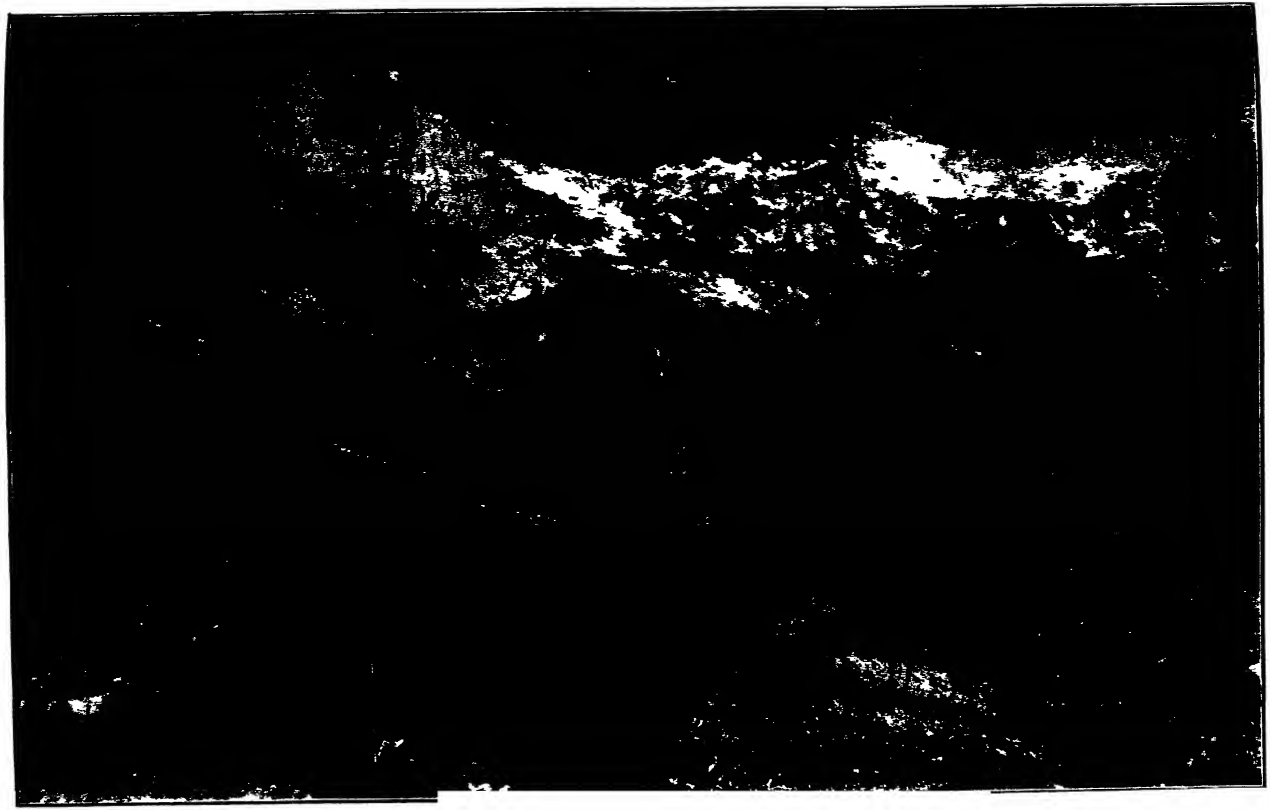
G. S. I. Calcutta.



Photograph by G de P Cotter

COAL in PAKOKKU

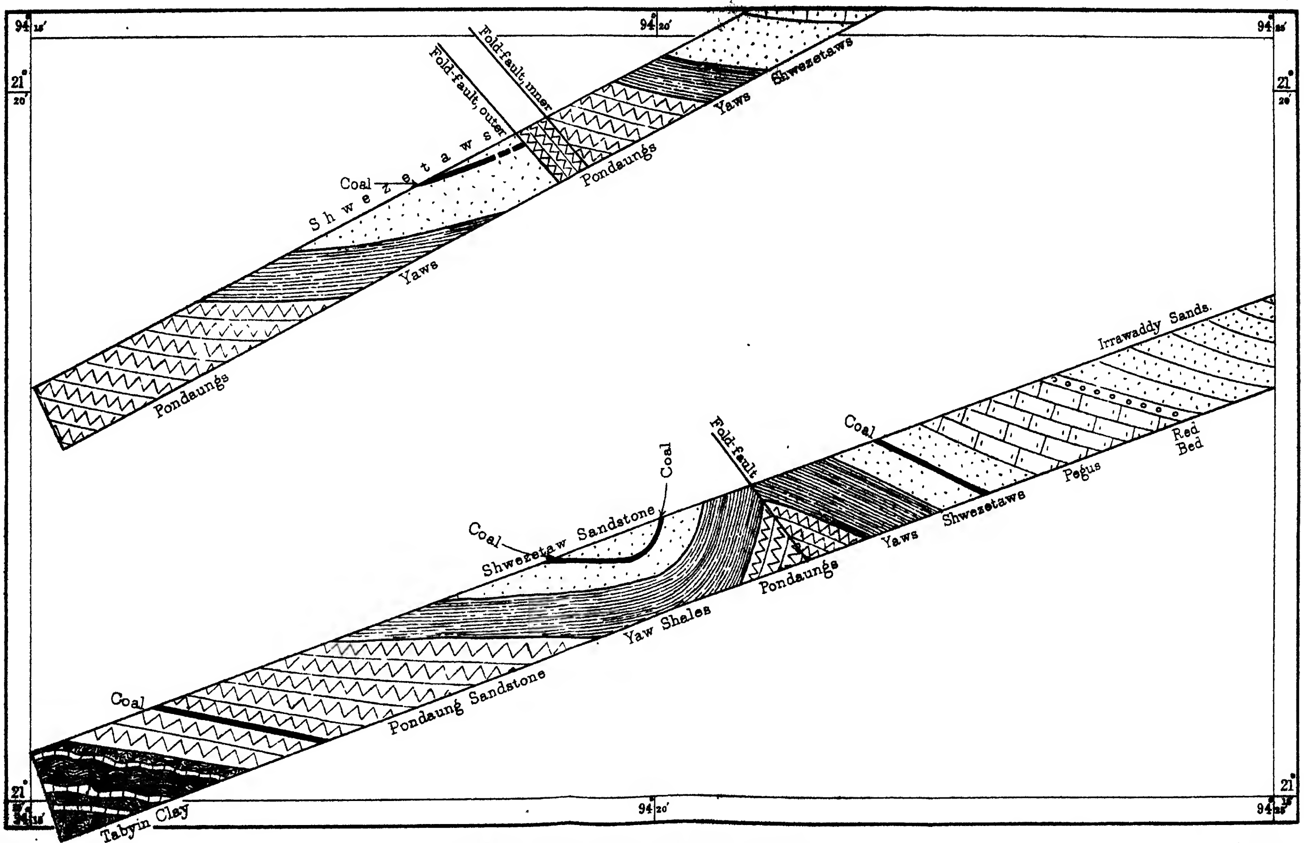
G S I Calcutta



Photograph by G. de P. Cotter

G. S. I. Calcutta

COAL in PAKOKKU



by G. de P. Cotter.

SECTION ACROSS MAP (Plate 10).

G. S. I. Calcutta.

Fig. 1 × 33

MONAZITE GRAINS SEPARATED MAGNETICALLY: LIPARUM, CAPE COMORIN.

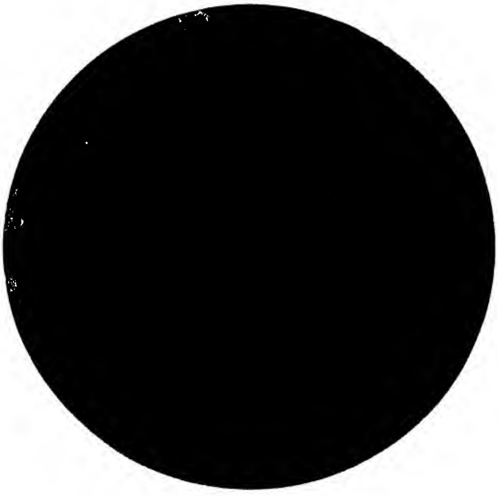


Fig. 2 × 11.

BLOWN SAND CEMENTED BY CALCITE: CAPE COMORIN.

M — Monazite.

Photographs by G H. Tipper.

G. S. I Calcutta

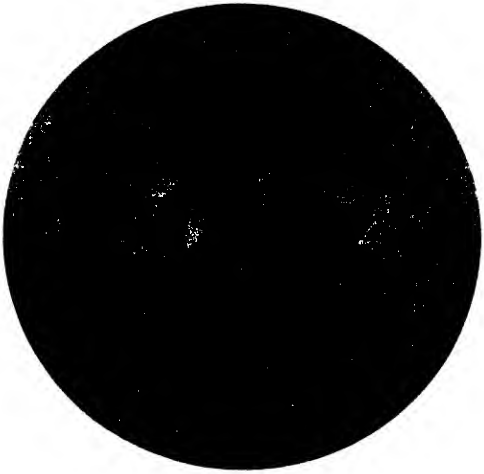


Fig. 1 × 11.

MONAZITE IN QUARTZ FROM PEGMATITE
WEST OF ESLANDIMANGALAM, TOVALA TALUQ, S TRAVANCORE

Fig 2 × 33. Crossed Nicols

TWINNED MONAZITE IN FELSPAR ·
WEST OF ESLANDIMANGALAM, TOVALA TALUK, S TRAVANCORE

Photographs by G H Tipper *G S I Calcutta*

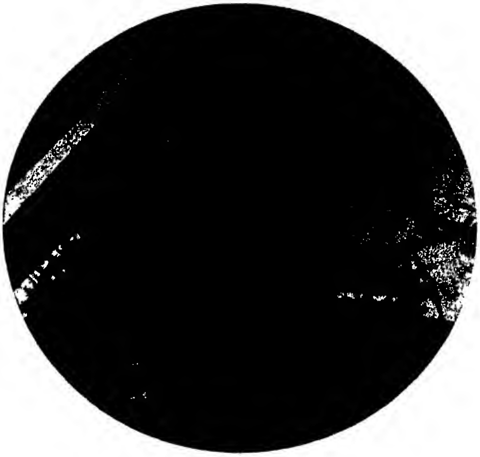


Fig. 1 × 11

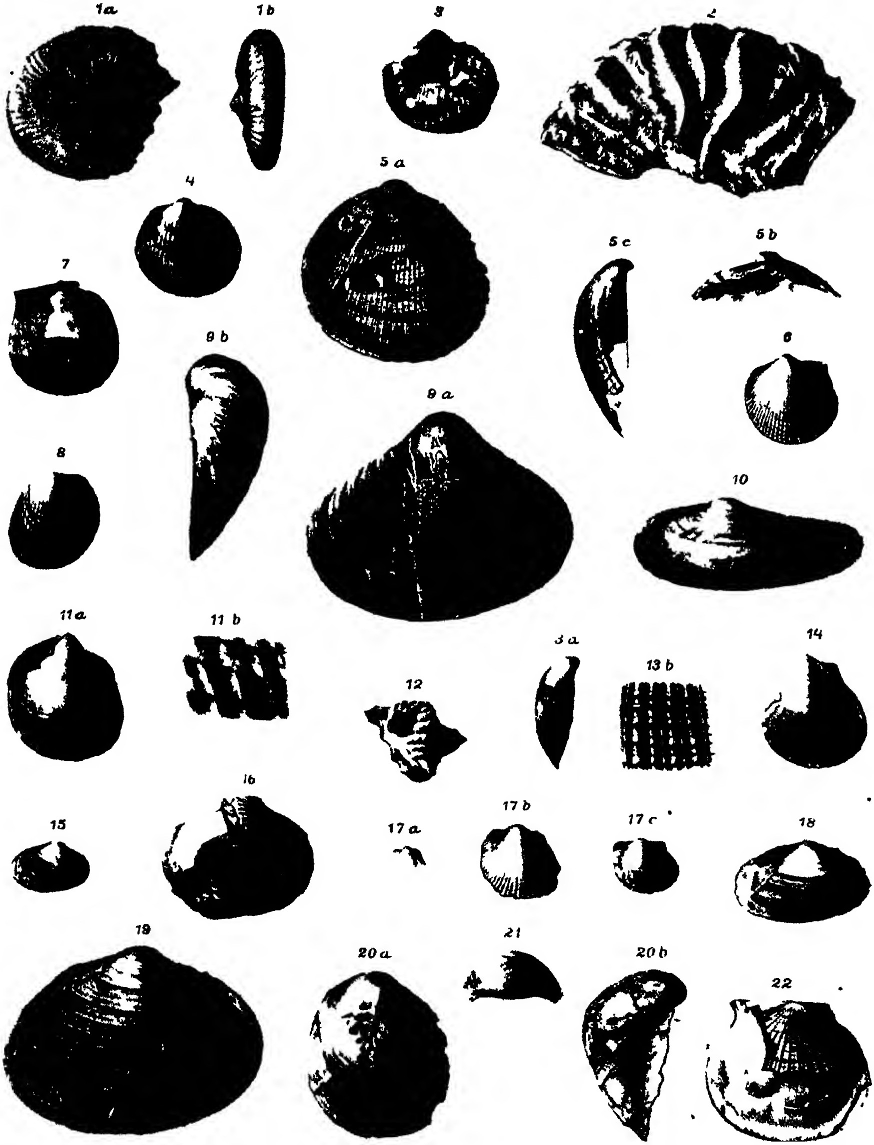
MONAZITE WITH BIOTITE, SEGREGATION PATCH IN PEGMATITE: ASHAMBOO TEA ESTATE RD., S. TRAVANCORE.

Fig. 2 × 11

MONAZITE-PEGMATITE, MONAZITE IN CONTACT WITH BIOTITE AND ILMENITE: LOCALITY UNKNOWN.

Photographs by G. H. Tipper *G. S. I. Calcutta*

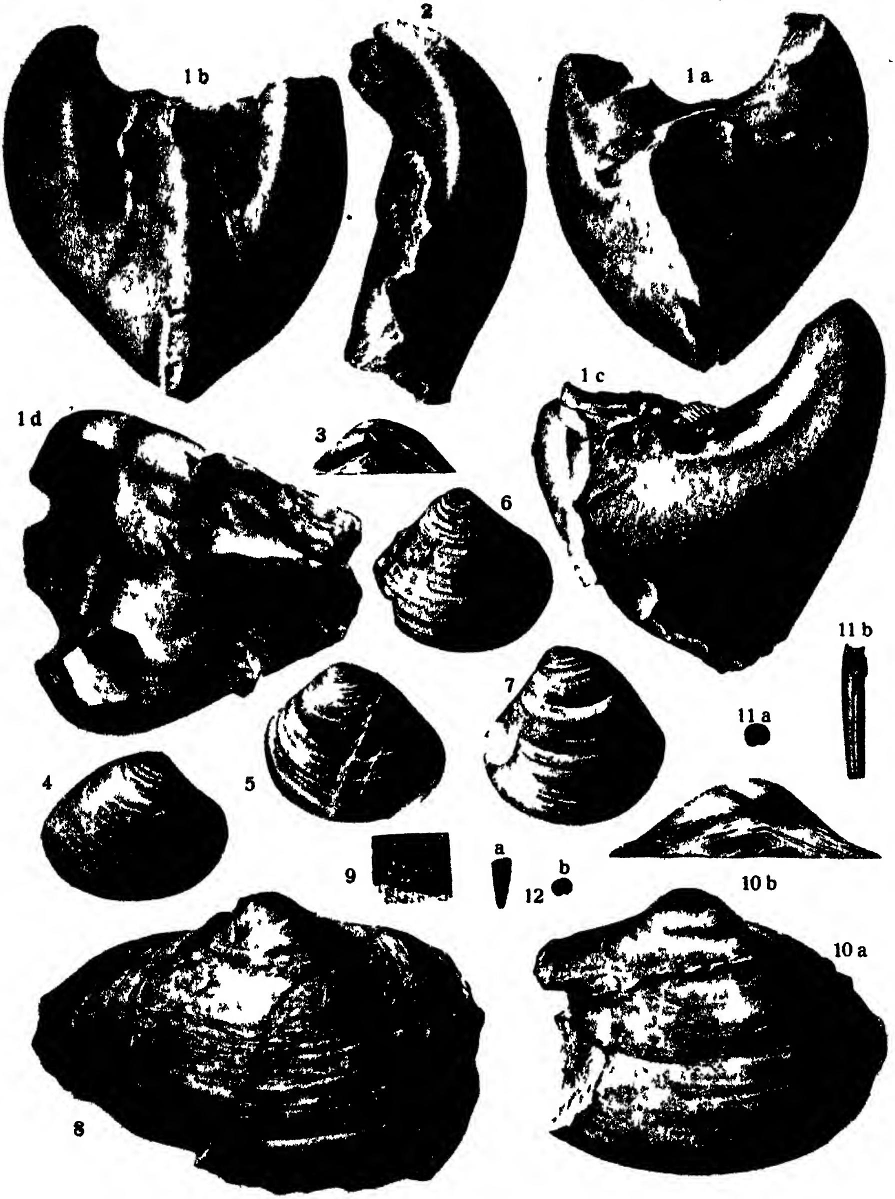
A. Spitz. Records, Vol XLIV, pl 18.



Sketch by J. Fleischmann, Vienna

A Berger print Vienna

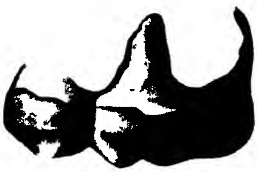
Cretaceous fossils from the Gieumal-sandstone and the Chikkim-series.



Sketch by Karl Reitschläger, Vienna. Phototypie, Max Jaffe, Vienna.

Cretaceous fossils from the Gieumal-sandstone and the Chikkim-series.

1



2

3

Fig 1 *Indarctos salmontanus,* Pilgrim, left maxilla, surface view.

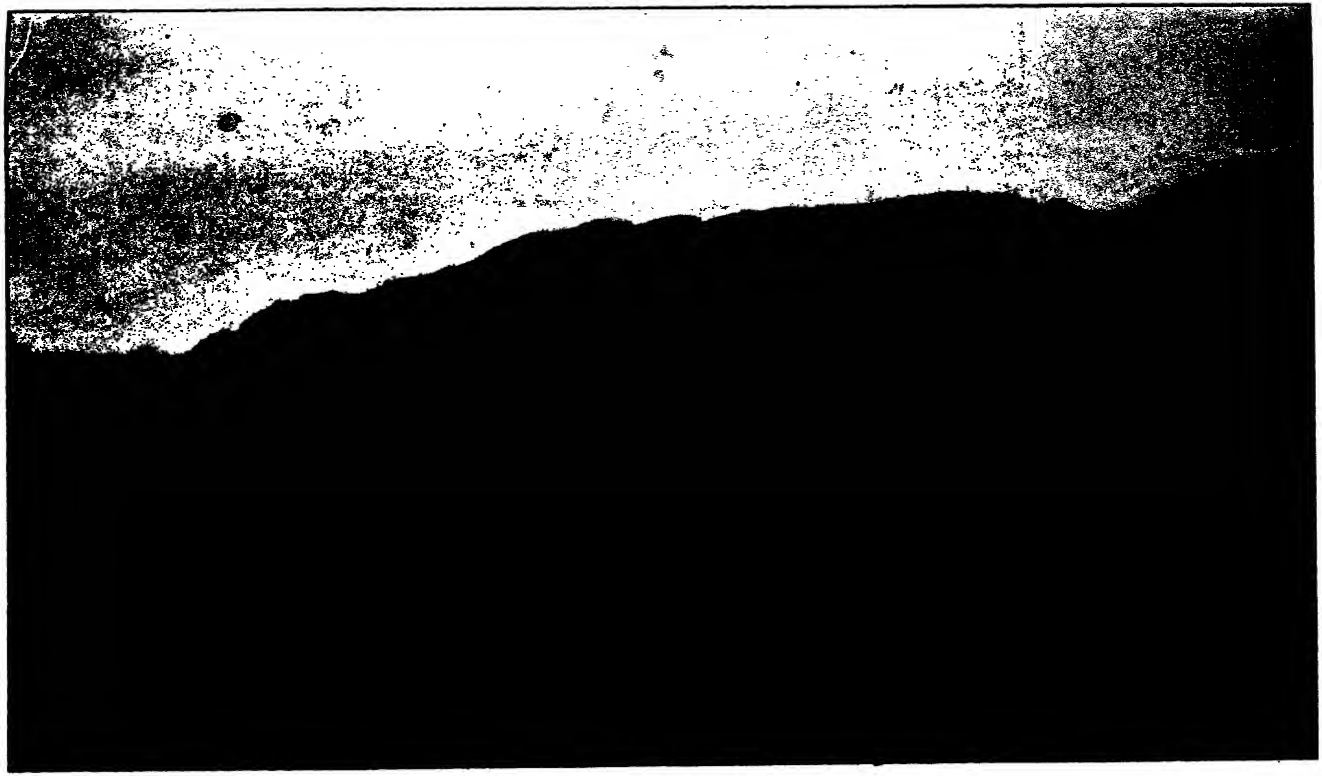
Fig. 2 m in the above, external side view.

Fig 3 The same internal side view.

(All figures natural size.)

G. M. Woodward, del.

G. S. I. Calcutta.



Photograph by W. A. K. Christie.

G. S. I. Calcutta.

MAYO MINES HILL, on the right.

G. S. I. Calcutta

INDEX TO PLATE 22.

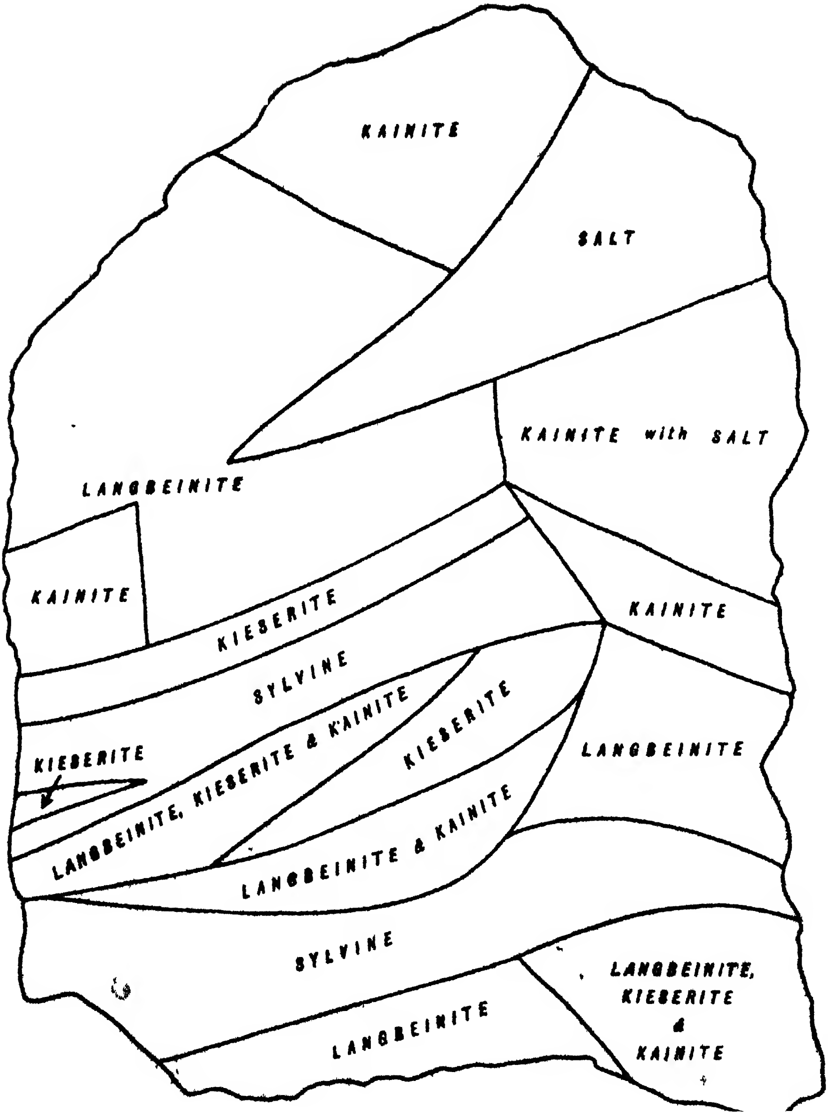
Photograph by W. A. K. Christie. G. S. I. Calcutta.

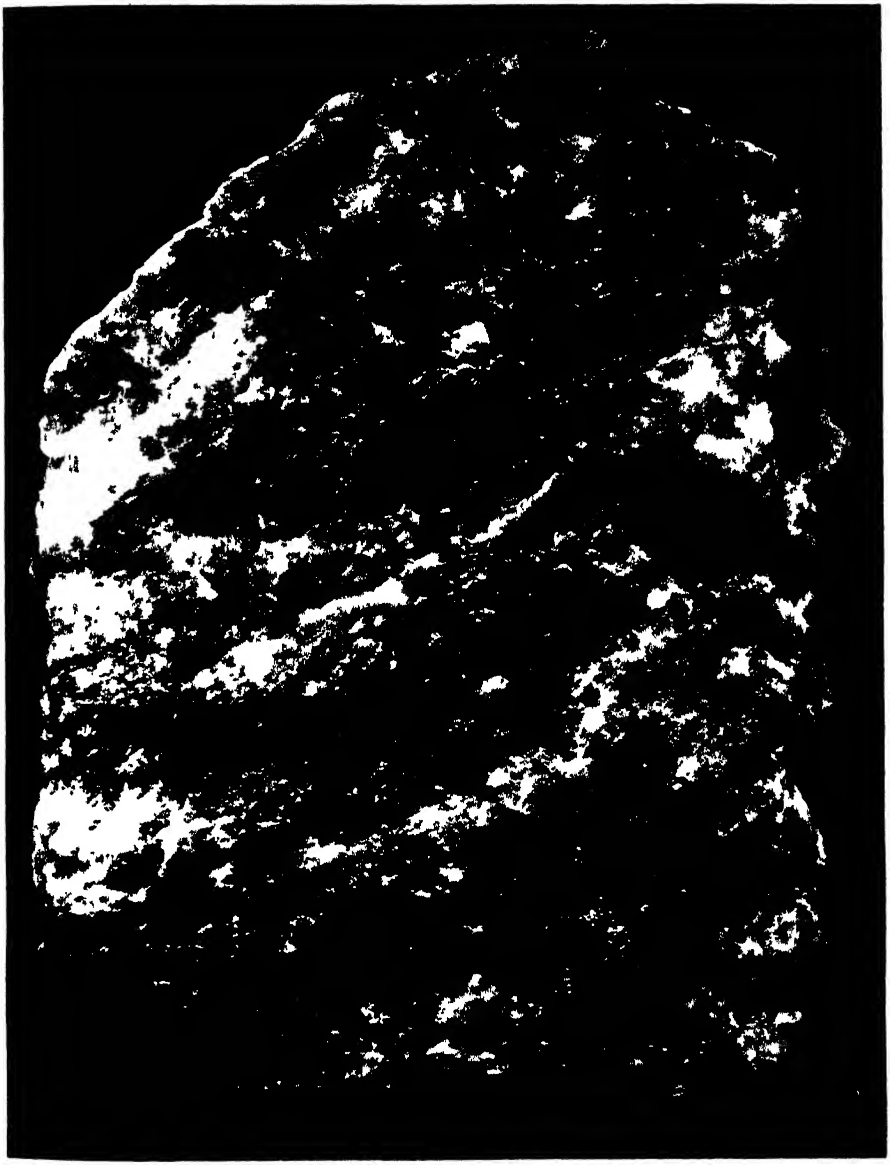
INTERIOR, MAYO MINES.

Flashlight photograph

Photograph by W. A. K. Christie. *G. S. I. Calcutta.*

MINER, MAYO SALT MINE.

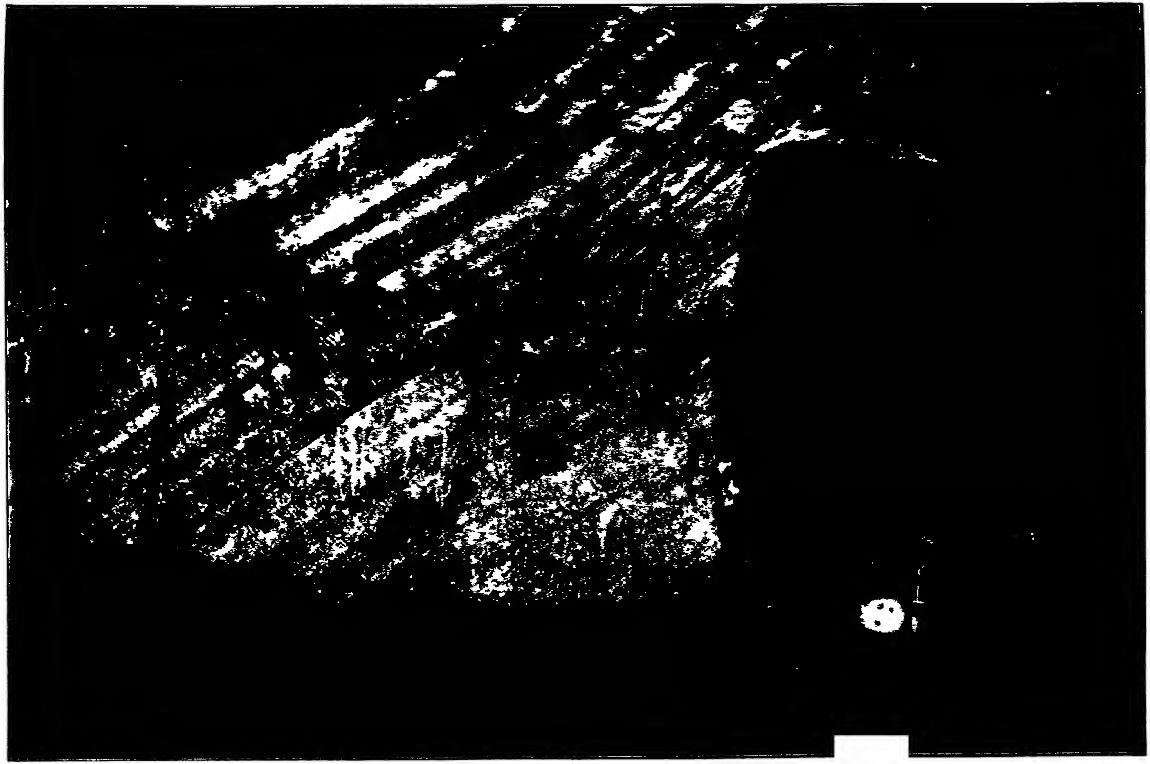

KAINITE
SALT
KAINITE with SALT
LANGBEINITE
KAINITE
KIESERITE
KAINITE
SYLVINE
LANGBEINITE, KIESERITE & KAINITE
KIESERITE
KIESERITE
LANGBEINITE
LANGBEINITE & KAINITE
SYLVINE
LANGBEINITE, KIESERITE & KAINITE
LANGBEINITE



Photograph by K F Watkinson *G S I. Calcutta.*

SPECIMEN FROM THE PHARWALA SEAM,

showing Minerological composition.



Photograph by H A K Christie

G. S I Calcutta.

MAYO SALT MINE, SHOWING STRATIFICATION.

Flashlight photograph

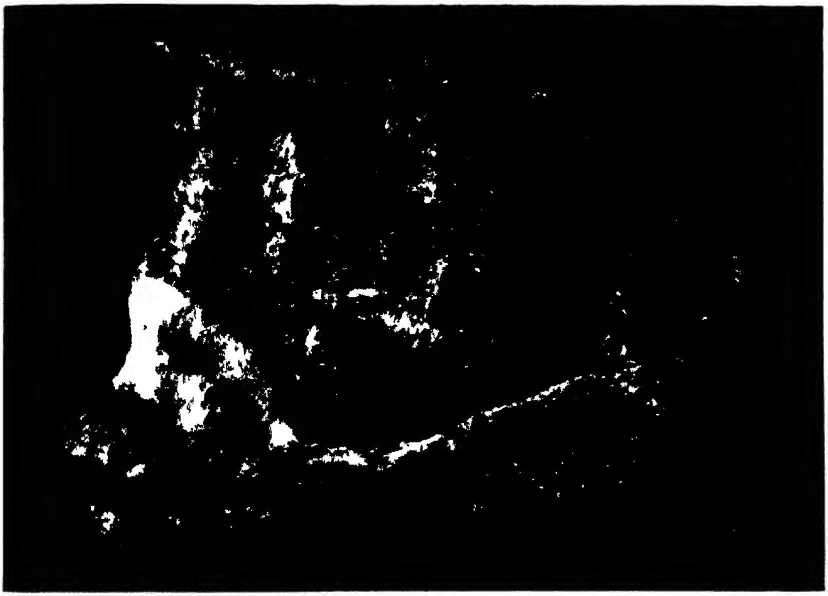
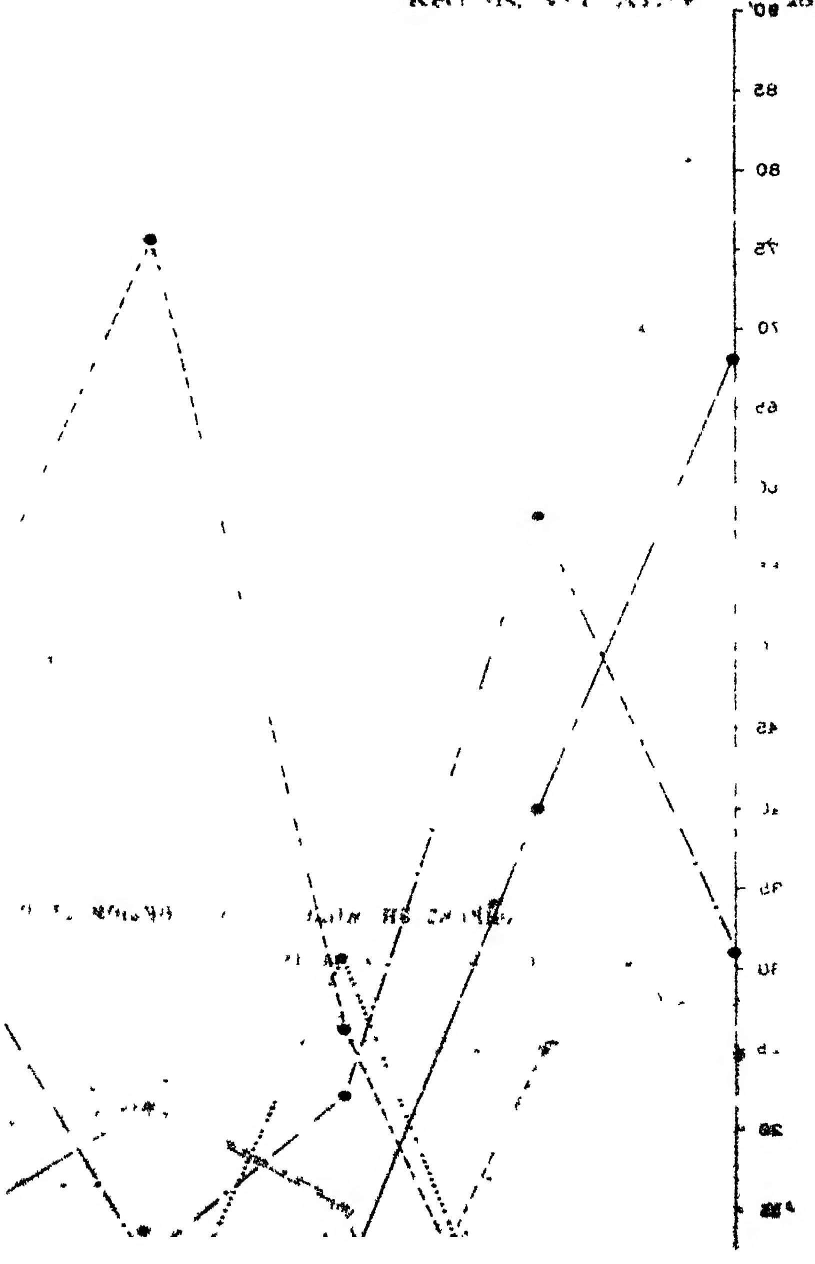
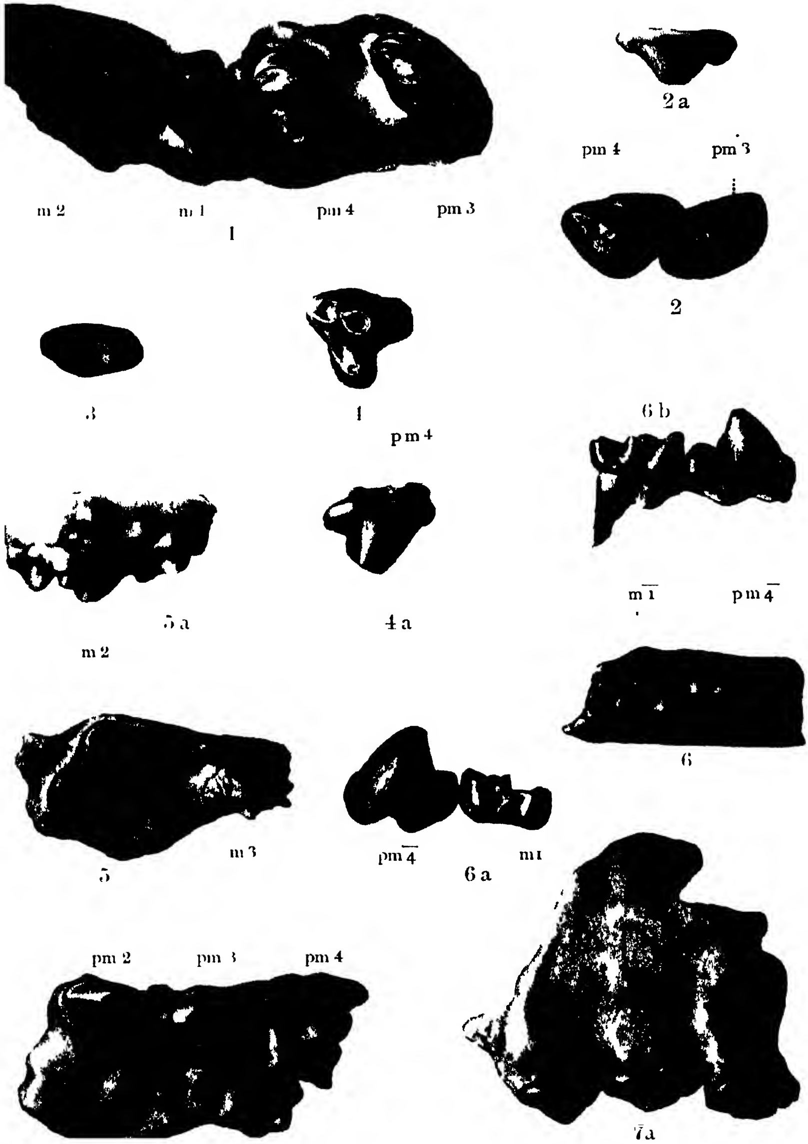


FIG. 1. FOLDED KIESERITE IN MARL, OVERLYING POTASH SEAM.

hotographs by K. F. Watkinson. *G. S. I. Calcutta.*

FIG. 2. SCHISTOSE STRUCTURE IN LANGBEINITE.

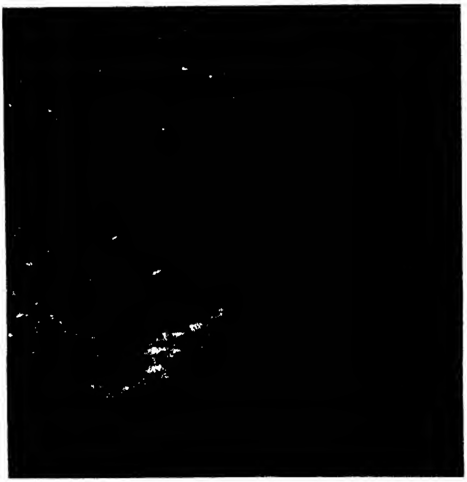




G M Woodward, del G S I CALCUTTA.

DISSOPSALIS CARNIFEX and RUBER.

FIG. 1 NORTHERN FEEDER of SONA GLACIER and ICE CAVE from ⊙ V



Photographs by J L. Grinlinton *G. S. I. Calcutta.*

FIG. 2. NAULPHU GLACIER (north branch) from NAULPHU ⊙ *a*.

Photographs by J. L. Grinlinton

G. S. I. Calcutta.

FIG. 1 SNOUT of SONA GLACIER from SONA ⊙ *a*.

FIG. 2 ICE CAVE, NIPCHUNGKANG GLACIER from ⊙ X.

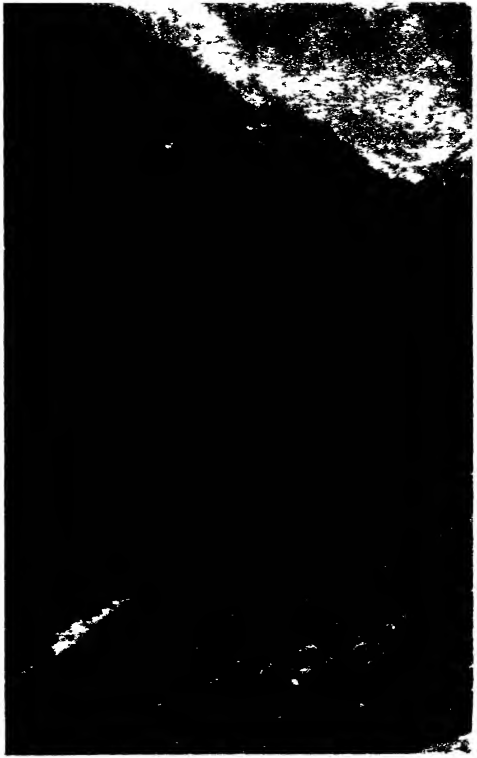


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FIG 1 ICE CAVE, NIPCHUNGKANG GLACIER from ⊙ IX

FIG 2 ICE CAVE, NIPCHUNGKANG GLACIER from ⊙ II

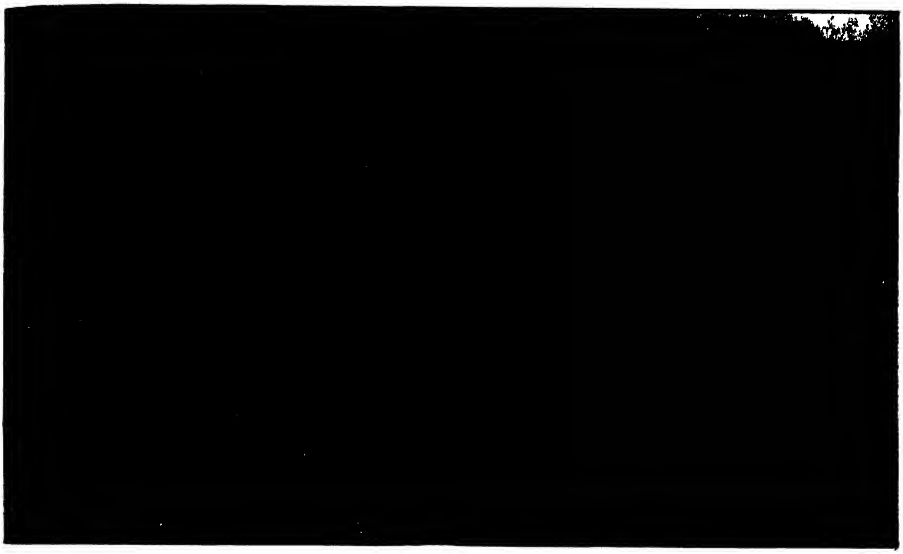


FIG 1. SNOUT and ICE CAVE of KHARSA GLACIER from KHARSA ⊙ η.

(retouched photograph)

Photographs by J. I. Grinlinton

G. S. I. Calcutta

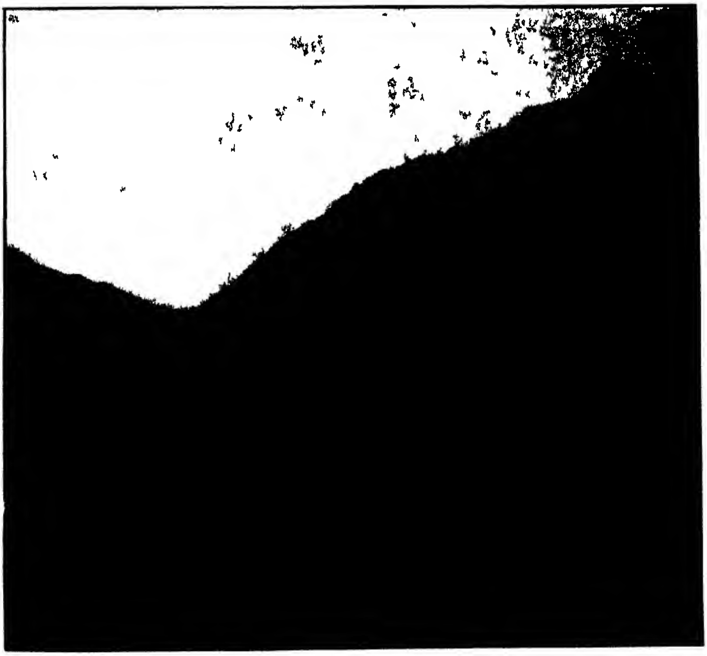
FIG. 2 KHARSA ICE CAVE, from KHARSA ⊙ β.

Photograph by J L Grinlinton

G. S. I. Calcutta.

ANCIENT MORAINES of CHOLUNGLI GLACIER near DAKAR and ZEGANY.

LOOKING UP THE DHAULI VALLEY FROM DAKAR VILLAGE.

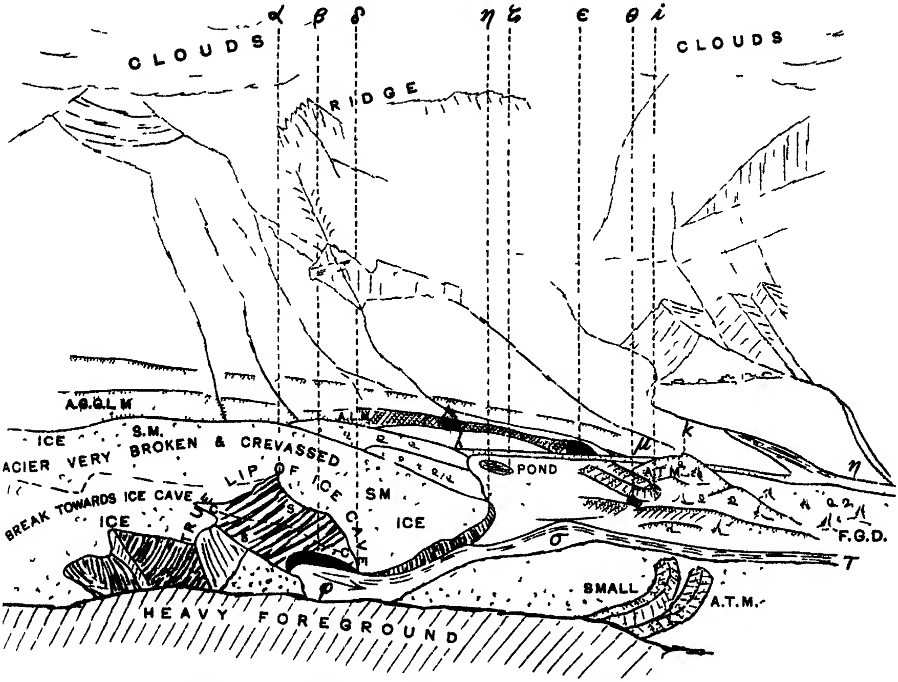


Photographs by J. I. Grinlinton

G. S. I. Calcutta

ANCIENT TERMINALS of KHARSA GLACIER in foreground,
looking down the Lissar Nadi from Kharsa ⊙ I

(retouched photograph)



SNOUT OF SONA GLACIER ON 6TH SEPT. 1912.

VIEW FROM SONA ⊙ III

BY CAPT J. L. GRINLINTON, R.G.A

α Lip of Ice cave.
β Issue of stream.
γ Lip of Ice cave.
δ Chasm in hill side.
η Ice foot on 6th September 1912.
ζ Morainic pond.
$\epsilon\alpha\,\mu$ Cut through by stream now almost dry.
θ Morainic pond.
i "Horseshoe" ancient terminal.
K Ancient terminal moraines.
$\lambda\,\mu\,\nu$ Dry bed of stream
$\phi\,\sigma\,\tau$ Present glacier stream on 6th. September 1912.

A.G.G.L.M. = Ancient grass grown lateral moraine.
A.T.M. = Ancient terminal moraines.
S.M. = Surface moraine

Mag. bearings (corrected).

α	=	309
β	=	313 ½
γ	=	317
δ	=	318
η	=	330
ζ	=	331 ½
ϵ	=	340 ¾
θ	=	343 ½
i	=	345 ¾
k	=	352 ½

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